January 5, 2022

Submitted Through FOIA Public Access Link (PAL)
CDC/ATSDR
Attn: FOIA Office, MS-D54
1600 Clifton Road, N.E.
Atlanta, GA 30333

Re: Freedom of Information Act Request regarding the 2010 Deepwater Horizon Incident

Dear Freedom of Information Act Officer:

Upon the direction of BP America Production Company and/or BP Exploration and Production ("BP"), National Institute for Occupational Safety and Health (NIOSH) investigators completed exposure monitoring, observational assessments, health surveys, and focus groups for a variety of work sites and work activities related to the Deepwater Horizon Oil Spill (DHOS). Per NIOSH Interim Report 4, attached as **Exhibit A**, the Health Hazard Evaluation (HHE) conducted Personal Breathing Zone (PBZ) air sampling for benzene and other Volatile Organic Compounds (VOCs) using passive Organic Vapor Monitors (OVMs) and charcoal tubes that were submitted for laboratory analyses. Charcoal OVM badges were placed on personnel identified as having the highest potential for exposure and charcoal tubes also were used to determine airborne concentrations of contaminants. The NIOSH HHE study findings were released in a series of nine interim reports as well as a final report published August 2011, attached as **Exhibit B**.[1] The NIOSH DHOS HHE mostly reported that contaminants were below Occupational Exposure Limits (OEL) or not detected in air monitoring and PBZ assessments. This includes onshore and offshore airborne contaminants for VOCs and Polycyclic Aromatic Hydrocarbons (PAHs) as well as monitoring of chemicals of concern in COREXIT dispersants.[2] In addition, dermal exposure risks were calculated primarily through observational methods.

Pursuant to the Freedom of Information Act (FOIA), 5 U.S.C. § 552, The Downs Law Group (DLG) requests any and all records[3] from April 20, 2010, to present, archived by NIOSH or the CDC regarding the following information and/or documents:

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[1] These reports are also publicly available at: https://www.cdc.gov/niosh/topics/oilspillresponse/gulfspillhhe.html.
[2] Further reference information regarding NIOSH's Deepwater Horizon Response Air Sampling Data can be found at https://www.cdc.gov/niosh/data/datasets/1004/default.html.
[3] Records shall include electronic records, as defined by the FOIA, of official and unofficial reports, meeting notes, emails and other communications.

1. NIOSH records, including any and all communications, regarding the decision to employ Organic Vapor Monitor (OVM) badges and charcoal tubes in the DHOS HHE study. This shall include any and all records concerning NIOSH discussions/meetings with Unified Area Command and United States Coast Guard (USCG), the Occupational Safety and Health administration (OSHA), and any other governmental entity during the DHOS response regarding:
    a. The use of the charcoal tubes and OVM badges.
    b. Any limitations of the charcoal tubes and OVM badges.
    c. Any impacts of humidity on the monitoring methods and/or OVM badges used in the HHE Reports.
    d. Any impacts of ultraviolet (UV) light on the monitoring methods and/or OVM badges used in the HHE Reports.
    e. Any impacts of high temperatures on the monitoring methods and/or OVM badges used in the HHE Reports.
    f. Discussions related to the various manufacturers of OVM products and the decision to use OVM badges.

2. NIOSH records, including any and all communications between NIOSH and BP, Center for Toxicology and Environmental Health ("CTEH"), Bureau Veritas, (Cardno)Entrix, ChemRisk, Total Safety, Analytical Resources, Inc., Heritage Research Group, ALS, Battelle, Galson Labs, Pace Analytical, Lancaster Laboratories, Eurofin, TDI Brooks, B&B Laboratories, Weatherford Laboratories, Columbia Analytical Services (CAS), Calscience Environmental Laboratories, Environmental Enterprises USA, Lawrence Berkley National Laboratory (LBNL), TestAmerica, Air Toxics Ltd., Gulf Coast Analytical Laboratories (GCAL), Harte Research Institute, Intertek, Ocean Veritas, Pacific Ecorisk, Smithers Viscient, Peak Petroleum Testing, Sherry Laboratories, Spectra Laboratories, Exponent, Industrial Economics, Inc., Southern Petroleum Labs (SPL, Inc.), Accutest Laboratories, Zymax Forensics, Dade Moeller, or any other private entity concerning the decision to employ OVM badges and charcoal tubes and any other methods of nearshore, onshore, or offshore air monitoring during the NIOSH HHE sampling and analysis.

3. NIOSH records concerning sampling validation protocols used to evaluate or analyze the OVM badges and tubes for PBZ air sampling in the DHOS HHE study. Any and all data related to the testing conditions used to calibrate the OVM badges and tubes for PBZ air sampling prior to use in the field. Any and all data comparing the actual field conditions to testing conditions used to calibrate the OVM badges and tubes for PBZ air sampling, including but not limited to records of humidity, UV light, temperature, and other environmental conditions recorded in the field during the HHE study where OVM badges and tubes were employed.

4. NIOSH records concerning efforts to employ observational methods to determine dermal exposure risks as well as the records of dermal exposure assessments by NIOSH. This request includes any reports concerning dermal or ingestion exposures recorded during the DHOS HHE NIOSH study. This request also includes reports and/or data and communications concerning whether NIOSH followed its own recommendation to combine the results of dermal and/or ingestion routes of exposure with airborne sampling results to assess the total Occupational Exposure Limits (OEL) and overall health risks to oil spill response and cleanup workers.

5. NIOSH records concerning the decision to use handheld digital monitors or other electronic devices to input sampling results. Any documents concerning the hiring and training of NIOSH technicians that worked on the Deepwater Horizon Response efforts and investigations related to HHEs, and their qualifications.

6. Any and all documentation or communications authored or maintained by NIOSH concerning the sampling methods employed for the DHOS HHE. This is to include any communications and correspondence between NIOSH, the Environmental Protection Agency (EPA), the US Coast Guard (USCG), the Occupational Safety and Health Administration (OSHA), the Department of Health and Human Services (DHHS), and/or any other federal or state agency commenting and/or advising on the NIOSH HHE sampling methodology and NIOSH HHE study results. This request is to also include communications, email or otherwise, between NIOSH and BP, and BP's DWH subcontractors including, but not limited to, Center for Toxicology and Environmental Health ("CTEH"), Bureau Veritas, (Cardno)Entrix, ChemRisk, Total Safety, Analytical Resources, Inc., Heritage Research Group, ALS, Battelle, Galson Labs, Pace Analytical, Lancaster Laboratories, Eurofin, TDI Brooks, B&B Laboratories, Weatherford Laboratories, Columbia Analytical Services (CAS), Environmental Enterprises USA, Lawrence Berkley National Laboratory (LBNL), TestAmerica, Air Toxics Ltd., Gulf Coast Analytical Laboratories (GCAL), Harte Research Institute, Intertek, Pacific Ecorisk, Smithers Viscient, Peak Petroleum Testing, Sherry Laboratories, Spectra Laboratories, Exponent, Industrial Economics *Inc*., Southern Petroleum Labs (SPL, Inc.), Accutest Laboratories, Zymax Forensics, and Dade Moeller, or concerning the NIOSH DHOS HHE sampling method selection, process, and results/reports.

7. Any and all communications between NIOSH and 3M—the manufacturer of the sampling tubes and badges—concerning the use of the OVM and PBZ sampling methods/monitoring devices during the NIOSH DHOS HHE.

8. Any and all communications between the NIOSH, BP and any federal, state, university, or private entities and laboratories involved in the NIOSH Health Hazard Evaluation (HHE) study during the Deepwater Horizon Oil Spill (DHOS) response.

9. Any and all communications between NIOSH, BP and any federal, state, university, or private entity involved in the sampling, testing, reporting or auditing of the NIOSH DHOS HHE reports, including memoranda, referral documents, notes, jottings, determinations, or recommendation documents.

10. All contracts, memoranda of understanding, written agreements, and communications between NIOSH, the CDC, ATSDR, EPA, DHHS, USCG, NOAA and the following private companies from April 20, 2010 through April 20, 2013: BP, 3M, SKC LLC., B&B Labs, Galston Labs, Pace Analytical, Bureau Veritas, Total Safety, Exponent, ChemRisk, Cardno, Entrix, Center for Toxicology and Environmental Health (CTEH), NALCO, and/or Ecolab (now ChampionX).

Records requested above may include any and all investigative documents, notes, photographs, videos, research, scientific studies, assessments, laboratory conducted sampling, testing, and results, and any final determinations or action plans resulting from said findings.

If any of the material covered by this request has been destroyed or removed, please provide all surrounding documentation including, but not limited to, a description of the action taken regarding the materials and justification for those actions taken.

For any documents or portions you deny due to a specific FOIA exemption, please provide a detailed justification of your grounds for claiming such exemption, explaining why the exemption is relevant to the document or portion of the document withheld.

We anticipate that any responsive documents will be unclassified. If any of the responsive documents contain classified information, please segregate all unclassified material within the classified documents and provide all unclassified information. We offer our assistance to work with your office to prioritize responsive data for this request, further refine the request if you find any terms too imprecise, conduct searches for unclassified responsive records, or engage in any other reasonable activities that would lessen the agency's burden and costs.

Presumption of Disclosure

In the absence of guidance from the Trump or Biden Administrations, the current presidential guidance comes from President Obama's 1/21/2009 memo, in which he declared the following policy for Executive Branch agencies:

> *The Freedom of Information Act should be administered with a clear presumption: In the face of doubt, openness prevails. … All agencies should adopt a presumption in favor of disclosure, in order to renew their commitment to the principles embodied in FOIA, and to usher in a new era of open Government. The presumption of disclosure should be applied to all decisions involving FOIA.*

The President's policy of openness was reiterated in guidelines issued on March 19, 2009, by Attorney General Eric Holder. Contained in those guidelines was the following direction:

> *First, an agency should not withhold information simply because it may do so legally. I strongly encourage agencies to make discretionary disclosures of information. An agency should not withhold records merely because it can demonstrate, as a technical matter, that the records fall within the scope of a FOIA exemption.*

Because of these polices, all requested records should be released in their entirety, except in cases where release is explicitly prohibited by law.

In order to help to determine my status to assess fees, you should know that I am affiliated with a private law firm and am seeking information for use in the firm's ongoing litigation against BP. However, the information requested is of public interest and therefore should be considered for a waiver or reduction of fees. Regardless, DLG is willing to pay fees for this request up to a maximum of $300. If you estimate that the fees will exceed this limit, please inform us first.

In addition, we are requesting expedited processing of this time sensitive request on the grounds that this information is urgently needed to properly inform the public, as well as a judge and jury in numerous lawsuits against BP concerning the human health impacts of the BP oil spill. DLG represents hundreds of adults and children in the Back End Litigation (BELO) phase of the BP Chronic Health class action settlement as well as hundreds of non-class members. These cases are on track for trial imminently this year or early next, and there is a strong public interest in favor of resolving the medical claims resulting from this unprecedented environmental catastrophe caused by BP in 2010.

Thank you for your consideration and prompt attention to this request.

Respectfully,

/s/ Craig Downs

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EXHIBIT

A

Health Hazard Evaluation of Deepwater Horizon Response Workers

Srinivas Durgam, Christine West, Steve Ahrenholz, Dave Sylvain, and John Gibbins

Health Hazard Evaluation Interim Report 4
August 11, 2010

CDC Workplace Safety and Health
National Institute for Occupational Safety and Health NIOSH
HealthHazard Evaluation Program

Interim report reissued December 2012: front and back covers, lead and contributing authors, and acknowledgments were added to the original interim report.

The cover photo shows support vessels spraying water on the flare side of the Q-4000 to prevent excessive heating of the ship's hull. The Q-4000 was part of the oil spill containment system that was burning oil and gas coming from the damaged Deepwater Horizon blowout preventer in the Gulf of Mexico: June 2010.

DEPARTMENT OF HEALTH AND HUMAN SERVICES

Public Health Service

National Institute for Occupational Safety and Health
Robert A. Taft Laboratories
4676 Columbia Parkway
Cincinnati OH 45226-1998

11 August 2010
HETA 2010-0115

Fred Tremmel
Deepwater Horizon ICP
1597 Highway 311
Houma, LA 70395

Dear Mr. Tremmel:

On May 28, 2010, the National Institute for Occupational Safety and Health (NIOSH) received a request from BP for a health hazard evaluation (HHE). The request asked NIOSH to evaluate potential exposures and health effects among workers involved in Deepwater Horizon Response activities. NIOSH sent an initial team of HHE investigators on June 2, 2010, to begin the assessment of off-shore activities. To date, more than three dozen HHE investigators have been on-scene.

This letter is the fourth in a series of interim reports. As this information is cleared for posting, we will make it available on the NIOSH website (www.cdc.gov/niosh/hhe). When all field activity and data analyses are complete we will compile the interim reports into a final report.

This report (Interim Report #4) includes several discrete components of our investigation. For each, we provide background, describe our methods, report the findings, and provide conclusions and, where appropriate, interim recommendations. The components included in this report are as follows:

- 4A – Evaluation of Vessels of Opportunity (VoOs) June 10–20, 2010
- 4B – Evaluation of Health Effects in Workers Performing Oil Skimming from Floating City #1, June 19–23, 2010
- 4C – Evaluation of Source Control Vessels Development Driller II and Discoverer Enterprise, June 21-23, 2010

Thank you for your cooperation with this evaluation. If you have any questions, please do not hesitate to contact me at 513.841.4382 or atepper@cdc.gov.

Sincerely yours,

Allison Tepper

Allison Tepper, PhD
Chief
Hazard Evaluations and Technical
Assistance Branch
Division of Surveillance, Hazard
Evaluations and Field Studies

3 Enclosures

cc:
Mr. David Dutton, BP
Dr. Richard Heron, BP
Dr. Kevin O'Shea, BP
Mr. Joe Gallucci, BP
Ms. Ursula Gouner, Transocean
CDR Laura Weems, USCG
Mr. Clint Guidry, LA Shrimp Association
Ms. Cindy Coe, OSHA
Dr. Raoul Ratard, LA DHHS
Mr. Brock Lamont, CDC

Interim Report #4A
Evaluation of Vessels of Opportunity (VoOs), June 10–20, 2010

Lead Author: Srinivas Durgam
Contributing Authors: Greg Burr, Nancy Burton, James Couch, Chad Dowell, Kenny Fent, Bradley King, and Robert McCleery

Introduction

The Vessels of Opportunity (VoO) program was established by BP in response to the April 20, 2010, Deepwater Horizon explosion and resultant oil spill in the Gulf of Mexico. As part of this program, local vessel owners contracted their boats to conduct a variety of oil spill response activities including booming and skimming operations, supporting on-site burning of surface oil, tar ball recovery, and providing transportation of supplies and personnel [BP 2010]. During June 10–20, 2010, NIOSH industrial hygienists conducted industrial hygiene assessments on six fishing and shrimping trawlers in the VoO program that were contracted by BP to remove surface oil by booming and skimming. These trawlers typically ranged in size from 20 feet to more than 65 feet in length. On days when oil was not present on the water surface in the areas to which these vessels were assigned, the vessel captains often directed their vessels through patches of foam (described by the crew as "dispersant foam") found on the sea surface to break them up. The vessels were typically staffed by a captain and 1–2 deckhands who stayed on the boat and 1–2 responders responsible for doing oil clean-up work on the VoOs. These responders were contract employees and were transported to the VoOs by crew boats on a daily basis.

The VoOs evaluated were assigned under Group 1 Command which was divided into five task forces, each of which was composed of five strike teams. Each strike team had five VoOs with a designated strike team leader. The five task forces in Group 1 Command were located across a large geographic area of the Gulf of Mexico, specifically from Breton Sound, Louisiana to the east of the southwest pass of the Mississippi River. The VoOs were required to be out to sea from 6:00 a.m.to 6:00 p.m. scouting for oil and conducting clean-up work when oil was discovered. The vessels typically traveled at speeds of less than 3.5 knots when scouting oil and traveled even slower (1–1.5 knots) when booms were used to skim oil. Because of their size, most VoOs stayed within a three nautical mile zone from shore. VoOs greater than 65 feet in length could travel beyond this three nautical mile zone. The VoOs docked overnight in safe harbors near the shore.

In addition to the VoOs, each task force had an Off Shore Vessel (OSV) that stayed anchored out at sea. The OSVs are greater than 150 feet in length and have large open decks. The OSVs stored the clean-up supplies used by the VoOs including personal protective equipment (PPE), fuel, and water and were responsible for distributing these items to the VoOs. They also stored on their decks the used absorbent booms and other contaminated materials used by VoO workers during oil clean-up work.

Group 1 Command was based at Floating City #1 and was responsible for providing the VoOs with the responders, food, and other supplies as needed. Floating City #1 was located at the north tip of Baptiste Collette Bayou and had the capability of housing 225 personnel. On a typical morning, the responders met at 5:30 a.m. to discuss safety issues of importance, followed by transport to their respective VoOs by a number of crew boats. Upon completion of the work shift, the responders were brought back by crew boats to the Floating City #1. The total time the responders spent traveling on the crew boats to and from their assigned VoOs typically ranged from 4–6 hours per day.

Responders and VoO personnel who conducted oil clean-up work were provided and required to wear yellow POSIWEAR®UB™ chemical protective suits, disposable nitrile gloves, 12” PIP ProCoat® PVC dipped chemical resistant gloves, steel toe rubber boots, safety glasses, hard hats, and personal flotation devices. In addition, nitrile gloves were required when cleaning the hard booms with diluted chemical cleaners.

Six different VoOs were evaluated by NIOSH industrial hygienists from June 10–20, 2010. General area (GA) and personal breathing zone (PBZ) air sampling was conducted on June 10, 2010 on board the Miss Brandy; on June 15, 2010 on board the Talibah II and the Pelican; on June 16, 2010 on board the North Star and the St. Martin; and on June 20, 2010 on board the Miss Carmen. Specifications for each VoO are shown below in Table 1. The determinations on which strike teams and VoOs to which the NIOSH industrial hygienists would be directed was made by Group 1 Command staff based on oil collection reports from the previous few days.

Table 1. Specifications of VoOs on which air sampling was conducted from June 10–20, 2010

Sampling Date	VoO	Task Force/ Strike Team	Dimensions (feet)	Personnel	Fuel	Smoking Inside/Outside Cabin
6/10/2010	Miss Brandy	TF-5/ST-5	72’ x 24’	Captain, 2 deckhands, 2 responders	Diesel	Yes/Yes
6/15/2010	Talibah II	TF-5/ST-1	38.5’ x 16’	Captain, deckhand, responder	Diesel	No/No
6/15/2010	Pelican	TF-5/ST-4	47’ x 18’	Captain, 2 deckhands, responder	Diesel	Yes/Yes
6/16/2010	North Star	TF-5/ST-3	62.7’ x 20’	Captain, 2 deckhands	Diesel	No/No
6/16/2010	St. Martin	TF-5/ST-5	60’ x 20’	Captain, 2 deckhands	Diesel	Yes/Yes
6/20/2010	Miss Carmen	TF-4/ST-2	46’ x 19’	Captain, deckhand, responder	Diesel	No/Yes

While coordinating and preparing for the evaluations on board the VoOs, the NIOSH industrial hygienists were informed that VoOs encountered oil patches around the Gulf of Mexico in a sporadic manner due to the oil movement caused by Gulf currents. During the evaluation on June 10, 2010, the captain of the Miss Brandy informed the NIOSH industrial hygienists that they had not encountered oil in over a week and half. The vessel was tasked to scout for oil in a specific grid location on the east side of the southwest pass of the Mississippi River. On the day of the NIOSH evaluation, Miss Brandy did not encounter oil. However, the vessel did encounter what was described by the personnel as “residual dispersant foam” present on the sea surface. The vessel spent time breaking up the long foam patches by driving through them. Other VoOs in the nearby area were also performing the same operation. The captain, deckhands, and responders spent most of their work shift inside the air conditioned cabin.

NIOSH industrial hygienists were transported to different VoOs on June 15, 16, and 20, 2010, to conduct evaluations during oil booming and clean-up activities on these vessels. However, similar to the evaluation on the Miss Brandy, no oil was encountered by these VoOs during the times when NIOSH industrial hygienists were on board. The vessels did encounter similar foam patches which were broken up by driving the boats through it. During these evaluations, VoO personnel and responders on the vessels spent most of their time in the air conditioned cabins.

Evaluation

NIOSH investigators conducted longer-term PBZ and GA air sampling on six different VoOs from June 10–20, 2010. The sampling period for longer-term air samples on each vessel was 4–6 hours because NIOSH industrial hygienists were directed to specific VoOs later in the morning of the day of the evaluation once coordinates of the VoOs were determined by Group 1 Command staff. Additionally, the responders were picked up approximately 2–3 hours before the end of the work day to allow for adequate time to travel back to Floating City #1. Although sampling times were less than the actual twelve hour shift times, the air sampling data represents worker exposures during the time when the responders were present on the VoOs. Shorter-term air samples evaluating specific tasks were not collected due to the lack of oil clean-up work activities on the days of the NIOSH evaluations.

To evaluate the presence of volatile organic compounds (VOCs), NIOSH investigators used integrated air sampling with a variety of sampling media, including multi-sorbent thermal desorption tubes followed by thermal desorption/gas chromatography-mass spectrometry (NIOSH Method 2549) and activated charcoal tubes [NIOSH 2010]. Results of the thermal desorption tube air samples were used to select specific VOCs for quantitation on PBZ and GA air samples collected using charcoal tubes. Other chemicals measured in PBZ or GA air samples using integrated air sampling techniques included propylene glycol (a component of the dispersant), diesel exhaust, mercury (a possible component of crude oil), and the benzene soluble fraction of total particulate samples. Direct reading measurements were made for carbon monoxide (CO) and hydrogen sulfide (H_2S). The sampling and analytical methods used are provided in Table 2.

Results

Table 3 contains a summary of the relevant occupational exposure limits (OELs) to which results were compared. Table 4 presents temperature and relative humidity (RH) measurements collected during the days when air sampling was conducted by the NIOSH industrial hygienists. The deck temperatures for the six VoOs ranged from 67˚F–106˚F and the RH ranged from 30%–87%. The temperature inside the vessels' cabins ranged from 66˚F–89˚F and the RH ranged from 29%–72%.

Volatile Organic Compounds
Seven thermal desorption tube area air samples were collected to screen for VOCs on five of the six VoOs. The screening samples collected during these sampling visits contained a variety of substances. The major compounds detected on all vessels were C_9 to C_{15} aliphatic hydrocarbons (straight and branched alkanes). Additional compounds detected included benzene, toluene, xylenes, napthalenes, and other substances. Limonene was also found on screening samples collected on board the Pelican and the North Star.

Based on the results of the thermal desorption tube screening samples, 19 PBZ and GA charcoal tube air samples were quantitated for benzene, ethyl benzene, limonene, naphthalene, toluene, total hydrocarbons (THC) (as hexane), and xylenes. Results are shown in Tables 5–10. Air concentrations of chemicals for which the air samples were analyzed were all well below their applicable OELs. Of the six PBZ samples (collected on a deckhand and a responder on the Pelican and on a deckhand on the St. Martin), limonene, THC, toluene, xylenes, and ethyl benzene were present above the minimum quantifiable concentrations (MQC) (see Tables 7 and 9). Personnel on both VoOs spent time inside the cabin as well as outdoors but did not engage in oil clean-up related tasks. The highest THC PBZ concentration was 6.0 milligrams per cubic meter (mg/m^3) and was collected on a deckhand on board the Pelican. The highest THC GA concentration on any of the six vessels was 6.5 mg/m^3 and was collected inside the cabin of the Pelican. The THC GA concentrations were greater inside the cabins of North Star and St. Martin when compared to the outside concentrations. Although there is no OEL specifically for THCs, OELs for petroleum distillates and kerosene (two mixtures containing a similar range of hydrocarbons as was found on the initial thermal tube air samples) are 350 mg/m^3 as a work shift time weighted average as shown in Table 2. Limonene is one of the ingredients in cleaning agents, which might explain its presence in the air samples. Even on an additive basis, for any given exposure period, the mixtures of chemicals measured in the air are a fraction (<10%) of the acceptable levels.

One GA air sample collected on Miss Carmen was quantitated for 2-butoxyethanol, dipropylene glycol butyl ether, and dipropylene glycol methyl ether (potential components in cleaners and oil dispersant). None of the analytes were present in concentrations greater than their respective minimum detectable concentrations (MDC) (Table 10).

Propylene Glycol

The NIOSH industrial hygienists collected seven GA air samples for propylene glycol, a component of Corexit 9500A (Nalco Company, Sugar Land, Texas), the dispersant in use at the time of the NIOSH evaluation. One GA air sample was collected on the deck of each VoO. In addition, a NIOSH industrial hygienist collected one GA air sample inside the cabin of the North Star. Propylene glycol was not detected in six of the air samples and was present below the MQC in one air sample (Tables 5–10).

Diesel Exhaust

Emissions from diesel engines used to power the vessels are complex mixtures of gases and particulates. NIOSH uses elemental carbon (EC) as a surrogate index of exposure because the sampling and analytical method for EC is very sensitive, and a high percentage of diesel particulate (80%–90%) is EC. In comparison, tobacco smoke particulate (a potential interference when measuring diesel exhaust) is composed primarily of organic carbon (OC). Although OSHA and NIOSH have established OELs for some of the individual components of diesel exhaust (i.e., nitrogen dioxide, CO), neither agency has established an OEL for EC. However, the California Department of Health Services' Hazard Evaluation System & Information Service (HESIS) guideline for diesel exhaust particles (measured as EC) is 20 micrograms per cubic meter (µg/m^3) for an 8-hour TWA. One air sample for diesel exhaust was collected on the deck of each of the VoOs. As shown in Tables 5–10, EC concentrations ranged from 1.4–9.1 µg/m^3, below the HESIS guideline. The OC concentrations ranged from less than 10–31 µg/m^3. Furthermore, diesel exhaust was not a substantial part of these sample results because the ratio of EC to total carbon (the sum of EC + OC) ranged from 4.3%–48%, which is below the expected 60%–80% of EC to total carbon typically reported in diesel exhaust.

Mercury
The NIOSH industrial hygienists collected five GA air samples for mercury of which four were collected on the decks of different VoOs and one was collected inside the cabin of North Star. Mercury air samples were not collected on the Miss Carmen. No mercury was detected in the five area air samples. The MDCs ranged up to 0.00005 mg/m^3, well below the most protective OEL of 0.025 mg/m^3.

Benzene Soluble Total Particulate Fraction
Two PBZ air samples (collected on deckhands on the Pelican and the St. Martin) and eight GA air samples (collected on all six VoOs) were collected for total particulates with the particulate fraction analyzed for benzene soluble components (to separate out contributions from substances like salts from the sea water) as an indicator of oil mist exposures (see Tables 5–10). Three of these eight GA air samples were collected inside the cabins of the Pelican, the North Star, and the St. Martin. None of the air samples contained detectable concentrations of benzene soluble particulates and none of the air samples returned results above the MQC for total particulates.

Carbon Monoxide and Hydrogen Sulfide
Tables 5–10 include a summary of the direct reading measurements for CO and H_2S. Carbon monoxide, a component of incomplete combustion, possibly from the diesel engines, was monitored on the deck and inside the cabins of various VoOs. Peak concentrations of CO ranged up to 15 parts per million (ppm), with the highest TWA of 6 ppm, well below OELs. Hydrogen sulfide was not detected on six area samples collected on the VoOs.

Summary

During this evaluation, the VoOs on which the NIOSH industrial hygienists were present spent most of their time scouting for oil and breaking up foam patches. Since no oil was encountered by these VoOs on these days, NIOSH investigators did not observe any oil clean-up work. The PBZ and area air concentrations of the measured compounds were all well below OELs.

Recommendations

The NIOSH industrial hygienists noted that employees were provided adequate PPE necessary to conduct their jobs. However, the potential for dermal contact with the weathered oil and cleaning agents exists when performing booming and skimming tasks. Due to this potential, it is recommended that all personnel conducting oil clean-up work on the VoOs ensure that the provided PPE is correctly worn during such work to prevent possible dermal exposures.

While respiratory protection was not a required component of PPE for the deckhands or responders conducting this oil clean-up work, a NIOSH industrial hygienist on one of the VoOs was shown a 3M™ half-mask respirator with organic vapor/acid gas P100 cartridges by one of the deckhands. The deckhand described the respirator as a part of the supplies provided to the boat. However, it was the only respirator provided to the vessel which had three permanent workers stationed on it. The deckhand noted that they were told that more respirators would be provided but were not delivered. It is recommended that any PPE determined to be needed by the oil spill command staff be provided in sufficient quantities for all workers present on the vessels. If respiratory protection is ever determined to be required as part of the PPE ensemble, all the elements of the OSHA Respiratory Protection Standard (29 CFR 1910.134), including fit testing, medical clearance, and proper training in the use of the respirators should be followed.

While on one of the VoOs, a NIOSH industrial hygienist inquired about the use of cleaners provided to the VoOs to clean their boats and booms. The deckhand responded that instructions had been provided to him for the proper dilution and application of the cleaner. NIOSH industrial hygienists recommend that proper training and instructions in the use of chemical cleaners be continued and that all VoO personnel working with such chemicals follow these instructions throughout the course of their work.

The NIOSH industrial hygienists observed widespread use of tobacco products, particularly cigarettes among the worker populations on most of the VoOs evaluated. Cigarette use by workers outside on the decks of vessels as well as inside cabins was observed. Smoking is the single most preventable cause of disease, disability, and death in the United States; an estimated 443,000 people die prematurely from smoking or exposure to secondhand smoke, and another 8.6 million have a serious illness caused by smoking [CDC 2010]. Eliminating cigarette smoking among Deepwater Horizon response workers on the VoOs would be the most desirable recommendation. From all the research on cigarette smoking, we know that quitting smoking has immediate as well as long-term benefits for smokers and those around them.

Acknowledgments

Field assistance and logistical support were provided by Donald Booher and Karl Feldmann. Analytical support was provided by Ardith Grote and Bureau Veritas North America.

References

ACGIH [2010]. 2010 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [2009]. AIHA 2009 Emergency response planning guidelines (ERPG) & workplace environmental exposure levels (WEEL) handbook. Fairfax, VA: American Industrial Hygiene Association.

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Table 2. Analytical methods used for substances evaluated during the June 10–20, 2010 VoOs evaluation

Analyte	Method
Benzene	NMAM 1501*†
Benzene soluble fraction of total particulates	NMAM 5042
2-Butoxyethanol	NMAM1403‡
Carbon monoxide	Direct reading—GasAlert CO Extreme, BW Technologies Ltd., Calgary, Canada
Diesel exhaust (elemental carbon, organic carbon, total carbon)	NMAM 5040
Dipropylene glycol butyl ether	NMAM1403‡
Dipropylene glycol methyl ether	NMAM1403‡
Ethyl benzene	NMAM 1501†
Hydrogen sulfide	Direct reading—GasAlert H_2S Extreme, BW Technologies Ltd., Calgary, Canada
Limonene	NMAM 1501†
Mercury	NMAM 6009
Naphthalene	NMAM 1501†
Propylene glycol	NMAM 5523
Relative humidity	Direct reading—HOBO® H8 ProSeries, Onset Computer Corporation, Bourne, Massachusetts
Temperature	Direct reading—HOBO® H8 ProSeries, Onset Computer Corporation, Bourne, Massachusetts
Toluene	NMAM 1501†
Total Hydrocarbons	NMAM 1501†
Volatile organic compounds (Screening)	NMAM 2549 and EPA TO-15§
Xylenes (Total)	NMAM 1501†

*National Institute for Occupational Safety and Health (NIOSH) Manual of Analytical Methods [NIOSH 2010]
†Analysis for selected volatile organic compounds by an adaptation of the method
‡Analysis by an adaptation of the method
§Environmental Protection Agency [EPA 1999]

Table 3. Occupational exposure limits for substances evaluated during the June 10–20, 2010 VoOs evaluation

Chemical	**NIOSH REL[a]**	**OSHA PEL[b]**	**ACGIH TLV[c]**	**AIHA WEEL[d]**
Benzene	0.1 ppm TWA[e] 1 ppm STEL[g]	1 ppm TWA 5 ppm STEL 0.5 ppm Action Level	0.5 ppm TWA 2.5 ppm STEL	N/A[f]
Benzene soluble fraction of total particulate	N/A	N/A	0.5 mg/m^3 TWA[h]	N/A
2-Butoxyethanol	5 ppm TWA	50 ppm TWA	20 ppm TWA	N/A
Carbon monoxide	35 ppm TWA 200 ppm Ceiling	50 ppm TWA	25 ppm TWA	N/A
Diesel exhaust (as elemental carbon)[i]	N/A	N/A	N/A	N/A
Dipropylene glycol butyl ether	N/A	N/A	N/A	N/A
Dipropylene glycol methyl ether	100 ppm TWA 150 ppm STEL	100 ppm TWA	100 ppm TWA 150 ppm STEL	N/A
Ethyl benzene	100 ppm TWA 125 ppm STEL	100 ppm TWA	100 ppm TWA[j] 125 ppm STEL	N/A
Hydrogen sulfide	10 ppm Ceiling (10 min)	20 ppm Ceiling[k]	1 ppm TWA 5 ppm STEL	N/A
Limonene	N/A	N/A	N/A	30 ppm
Mercury	0.05 mg/m^3 TWA[l]	0.1 mg/m^3 TWA[m]	0.025 mg/m^3 TWA[m]	N/A
Naphthalene	10 ppm TWA 15 ppm STEL	10 ppm TWA	10 ppm TWA 15 ppm STEL	N/A
Propylene glycol	N/A	N/A	N/A	10 mg/m^3
Toluene	100 ppm TWA 150 ppm STEL	200 ppm TWA 300 ppm Ceiling 500 ppm Peak (10 min max.)	20 ppm TWA	N/A
Total hydrocarbons	350 mg/m^3 TWA 1800 mg/m^3 Ceiling (15 min) (Petroleum distillates)	2000 mg/m^3 TWA (Petroleum distillates as naphtha)	200 mg/m^3 TWA (Kerosene as total hydrocarbon vapor)	N/A

Table 3. Occupational exposure limits for substances evaluated during the June 10–20, 2010 VoOs evaluation (continued)

Chemical	**NIOSH REL[a]**	**OSHA PEL[b]**	**ACGIH TLV[c]**	**AIHA WEEL[d]**
Xylenes	100 ppm TWA 150 ppm STEL	100 ppm TWA	100 ppm TWA 150 ppm STEL	N/A

[a]National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) [NIOSH 2005]
[b]Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) [29 CFR 1910]
[c]American Conference of Governmental Industrial Hygienists® (ACGIH) threshold limit value® (TLV) [ACGIH 2010]
[d]American Industrial Hygiene Association (AIHA) Workplace Environmental Exposure Level (WEEL) [AIHA 2009]
[e]TWA = time weighted average
[f]N/A = not applicable
[g]STEL = short term exposure limit
[h]This OEL is for asphalt (bitumen) fume as benzene soluble aerosol but was considered appropriate because this sampling was intended to differentiate between petroleum associated particulate and background particulate.
[i]California Department of Health Services' Hazard Evaluation System & Information Service (HESIS) guideline for diesel exhaust particles (measured as elemental carbon [EC]) is 20 µg/m^3 for an 8-hour TWA [CDHS 2002]
[j]Proposed to be changed to 20 ppm TWA and STEL eliminated [ACGIH 2010]
[k]Exposures shall not exceed with the following exception: if no other measurable exposure occurs during the 8-hour work shift, exposures may exceed 20 ppm, but not more than 50 ppm (peak), for a single time period up to 10 minutes
[l]Elemental form
[m]Elemental and inorganic forms

Table 4. Environmental conditions during the June 10–20, 2010 VoOs evaluation*		
Vessel	**Temperature (°F)***	**Relative Humidity (%)***
June 10, 2010		
Miss Brandy (Captain's Cabin)	71	54–55; 54
Miss Brandy (Dining Area)	71	55
Miss Brandy (Middeck above pulley)	70	56–57; 56
June 15, 2010		
Talibah II (Rear deck center)	87–91; 89	55–71; 64
Talibah II (Captain's cabin)	87–89; 88	62–66; 63
Pelican (In Cabin)	83–89; 85	29–61; 39
Pelican (On deck)	89–95; 93	48–65; 55
June 16, 2010		
North Star (Inside cabin)	66–77; 68	43–70; 55
St. Martin (On deck)	80–106; 94	30–72; 52
St. Martin (In cabin)	77–81; 81	37–72; 45
June 20, 2010		
Miss Carmen (Rear deck center)	67–92; 89	61–87; 69

*Reported as range; average
Hours of monitoring: approximately 9:00 a.m. – 4:00 p.m.

Table 5. Area air concentrations for substances measured on June 10, 2010 on the Miss Brandy				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Area Air Samples				
Starboard side deck	Benzene	341	67.9	<0.001 ppm
Starboard side deck	Benzene	340	68.7	<0.001 ppm
Starboard side deck	Benzene soluble fraction	338	671	<0.04 mg/m^3
Captain's Cabin	Carbon Monoxide	406	N/A	Range: 0–0 ppm; Avg: 0 ppm
Dining Area	Carbon Monoxide	412	N/A	Range: 0–0 ppm; Avg: 0 ppm
Middeck above pulley	Carbon Monoxide	401	N/A	Range: 0–0 ppm; Avg: 0 ppm
Portside of deck	Diesel exhaust	338	670	EC: (2.5 µg/m^3); OC: (31 µg/m^3)
Starboard side deck	Ethyl benzene	341	67.9	<0.0007 ppm
Starboard side deck	Ethyl benzene	340	68.7	<0.0007 ppm
Dining Area	Hydrogen sulfide	412	N/A	0 ppm
Middeck above pulley	Hydrogen sulfide	401	N/A	0 ppm
Portside of deck	Mercury	529	105	<0.00002 mg/m^3
Starboard side deck	Naphthalene	341	67.9	(0.0034 ppm)
Starboard side deck	Naphthalene	340	68.7	(0.0033 ppm)
Portside of deck	Propylene glycol	338	670	<0.001 mg/m^3
Starboard side deck	Toluene	341	67.9	<0.0008 ppm
Starboard side deck	Toluene	340	68.7	<0.0008 ppm
Starboard side deck	Total hydrocarbons	341	67.9	0.37 mg/m^3
Starboard side deck	Total hydrocarbons	340	68.7	0.37 mg/m^3
Starboard side deck	Total particulates	338	671	<0.06 mg/m^3
Starboard side deck	Xylenes	341	67.9	(0.0014 ppm)
Starboard side deck	Xylenes	340	68.7	(0.0014 ppm)

*N/A = not applicable
†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration
‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 6. Area air concentrations for substances measured on June 15, 2010 on the Talibah II				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Area Air Samples				
Rear deck center	Benzene	221	44.6	<0.002 ppm
Rear deck center	Benzene	219	43.3	<0.002 ppm
Rear deck center	Benzene soluble fraction	219	435	<0.2 mg/m^3
Captain's cabin	Carbon Monoxide	234	N/A	Range: 0–6 ppm; Avg: 1 ppm
Rear deck end	Carbon Monoxide	228	N/A	Range: 0–15 ppm; Avg: 2 ppm
Rear deck center	Diesel exhaust	224	446	EC: (1.6 µg/m^3); OC: <20µg/m^3
Rear deck center	Ethyl benzene	221	44.6	<0.001 ppm
Rear deck center	Ethyl benzene	219	43.3	<0.001 ppm
Rear deck end	Hydrogen sulfide	228	N/A	0 ppm
Rear deck center	Limonene	221	44.6	<0.0008 ppm
Rear deck center	Limonene	219	43.3	<0.0008 ppm
Rear deck center	Mercury	220	43.2	<0.00005 mg/m^3
Rear deck center	Naphthalene	221	44.6	<0.0009 ppm
Rear deck center	Naphthalene	219	43.3	<0.0009 ppm
Rear deck center	Propylene glycol	114	224	<0.004 mg/m^3
Rear deck center	Toluene	221	44.6	<0.001 ppm
Rear deck center	Toluene	219	43.3	<0.001 ppm
Rear deck center	Total hydrocarbons	221	44.6	(0.0099 mg/m^3)
Rear deck center	Total hydrocarbons	219	43.3	(0.014 mg/m^3)
Rear deck center	Total particulates	219	435	<0.09 mg/m^3
Rear deck center	Xylenes	221	44.6	<0.002 ppm
Rear deck center	Xylenes	219	43.3	<0.002 ppm

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 7. Personal breathing zone and area air concentrations for substances measured on June 15, 2010 on the Pelican				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Personal Breathing Zone Air Samples—Worker A§				
Deckhand	Benzene soluble fraction	247	480	<0.2 mg/m^3
Deckhand	Total particulates	247	480	(0.18 mg/m^3)
Personal Breathing Zone Air Samples—Worker B§				
Responder	Benzene	215	42.5	<0.002 ppm
Responder	Benzene	214	42.1	<0.002 ppm
Responder	Ethyl benzene	215	42.5	<0.001 ppm
Responder	Ethyl benzene	214	42.1	<0.001 ppm
Responder	Limonene	215	42.5	0.013 ppm
Responder	Limonene	214	42.1	0.0077 ppm
Responder	Naphthalene	215	42.5	<0.0009 ppm
Responder	Naphthalene	214	42.1	<0.0009 ppm
Responder	Toluene	215	42.5	<0.001 ppm
Responder	Toluene	214	42.1	<0.001 ppm
Responder	Total hydrocarbons	215	42.5	0.092 mg/m^3
Responder	Total hydrocarbons	214	42.1	0.059 mg/m^3
Responder	Xylenes	215	42.5	<0.002 ppm
Responder	Xylenes	214	42.1	<0.002 ppm
Personal Breathing Zone Air Samples—Worker C§				
Deckhand	Benzene	234	46.7	(0.0027 ppm)
Deckhand	Benzene	232	46.0	(0.0025 ppm)
Deckhand	Ethyl benzene	234	46.7	0.0084 ppm
Deckhand	Ethyl benzene	232	46.0	0.0085 ppm
Deckhand	Limonene	234	46.7	0.085 ppm
Deckhand	Limonene	232	46.0	0.085 ppm
Deckhand	Naphthalene	234	46.7	(0.013 ppm)
Deckhand	Naphthalene	232	46.0	(0.012 ppm)
Deckhand	Toluene	234	46.7	0.015 ppm
Deckhand	Toluene	232	46.0	0.016 ppm
Deckhand	Total hydrocarbons	234	46.7	5.8 mg/m^3
Deckhand	Total hydrocarbons	232	46.0	6.0 mg/m^3
Deckhand	Xylenes	234	46.7	0.035 ppm
Deckhand	Xylenes	232	46.0	0.035 ppm

Table 7. Personal breathing zone and area air concentrations for substances measured on June 15, 2010 on the Pelican (continued)				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Area Air Samples				
In Cabin	Benzene	236	46.0	(0.0031 ppm)
On deck	Benzene soluble fraction	249	497	<0.2 mg/m^3
In Cabin	Benzene soluble fraction	249	490	<0.2 mg/m^3
On deck	Carbon Monoxide	255	N/A	Range: 0–13 ppm; Avg: 3 ppm
On deck	Diesel exhaust	255	502	EC: (2.8 µg/m^3); OC: <20 µg/m^3
In Cabin	Ethyl benzene	236	46.0	0.0095 ppm
On deck	Hydrogen sulfide	256	N/A	0 ppm
In Cabin	Limonene	236	46.0	0.082 ppm
On deck	Mercury	236	46.2	<0.00004 ppm
In Cabin	Naphthalene	236	46.0	(0.012 ppm)
On deck	Propylene glycol	251	490	<0.002 mg/m^3
In Cabin	Toluene	236	46.0	0.017 ppm
In Cabin	Total hydrocarbons	236	46.0	6.5 mg/m^3
On deck	Total particulates	249	497	<0.08 mg/m^3
In Cabin	Total particulates	249	490	<0.08 mg/m^3
In Cabin	Xylenes	236	46.0	0.039 ppm

*N/A = not applicable
†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration
‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)
§Worker smoked

Table 8. Area air concentrations for substances measured on June 16, 2010 on the North Star				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Area Air Samples				
Inside Cabin	Benzene	218	43.3	<0.002 ppm
Inside Cabin	Benzene	217	44.1	<0.002 ppm
Outside rear center	Benzene	207	41.5	<0.002 ppm
Outside rear center	Benzene	208	40.6	<0.002 ppm
Inside Cabin	Benzene soluble fraction	223	442	<0.2 mg/m^3
Outside rear center	Carbon Monoxide	209	N/A	Range: 0–9 ppm; Avg: 6 ppm
Inside Cabin	Carbon Monoxide	214	N/A	Range: 0–0 ppm; Avg: 0 ppm
Outside rear center	Diesel exhaust	207	416	EC: (1.5 µg/m^3); OC: <20µg/m^3
Inside Cabin	Ethyl benzene	218	43.3	<0.001 ppm
Inside Cabin	Ethyl benzene	217	44.1	<0.001 ppm
Outside rear center	Ethyl benzene	207	41.5	<0.001 ppm
Outside rear center	Ethyl benzene	208	40.6	<0.001 ppm
Outside rear center	Hydrogen sulfide	209	N/A	0 ppm
Inside Cabin	Limonene	218	43.3	0.011 ppm
Inside Cabin	Limonene	217	44.1	0.011 ppm
Outside rear center	Limonene	207	41.5	(0.0010 ppm)
Outside rear center	Limonene	208	40.6	(0.0019 ppm)
Inside Cabin	Mercury	219	44.2	0.00005 mg/m^3
Inside Cabin	Naphthalene	218	43.3	<0.0009 ppm
Inside Cabin	Naphthalene	217	44.1	<0.0009 ppm
Outside rear center	Naphthalene	207	41.5	<0.0009 ppm
Outside rear center	Naphthalene	208	40.6	<0.0009 ppm
Inside Cabin	Propylene glycol	222	440	<0.002 mg/m^3
Outside rear center	Propylene glycol	206	401	(0.012 mg/m^3)
Inside Cabin	Toluene	218	43.3	(0.0028 ppm)
Inside Cabin	Toluene	217	44.1	(0.0029 ppm)
Outside rear center	Toluene	207	41.5	<0.001 ppm
Outside rear center	Toluene	208	40.6	<0.001 ppm
Inside Cabin	Total hydrocarbons	218	43.3	0.62 mg/m^3
Inside Cabin	Total hydrocarbons	217	44.1	0.63 mg/m^3
Outside rear center	Total hydrocarbons	207	41.5	0.059 mg/m^3
Outside rear center	Total hydrocarbons	208	40.6	0.12 mg/m^3
Inside Cabin	Total particulates	223	442	<0.09 mg/m^3
Inside Cabin	Xylenes	218	43.3	(0.0027 ppm)
Inside Cabin	Xylenes	217	44.1	(0.0028 ppm)
Outside rear center	Xylenes	207	41.5	<0.002 ppm
Outside rear center	Xylenes	208	40.6	<0.002 ppm

*N/A = not applicable
†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration
‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 9. Personal breathing zone and area air concentrations for substances measured on June 16, 2010 on the St. Martin				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Personal Breathing Zone Air Samples—Worker A§				
Deckhand	Benzene soluble fraction	224	434	<0.2 mg/m^3
Deckhand	Total particulates	224	434	<0.09 mg/m^3
Personal Breathing Zone Air Samples—Worker B§				
Deckhand	Benzene	221	44.3	<0.002 ppm
Deckhand	Benzene	220	43.0	<0.002 ppm
Deckhand	Ethyl benzene	221	44.3	<0.001 ppm
Deckhand	Ethyl benzene	220	43.0	<0.001 ppm
Deckhand	Limonene	221	44.3	0.011 ppm
Deckhand	Limonene	220	43.0	0.011 ppm
Deckhand	Naphthalene	221	44.3	<0.0009 ppm
Deckhand	Naphthalene	220	43.0	<0.0009 ppm
Deckhand	Toluene	221	44.3	(0.0041 ppm)
Deckhand	Toluene	220	43.0	(0.0044 ppm)
Deckhand	Total hydrocarbons	221	44.3	0.59 mg/m^3
Deckhand	Total hydrocarbons	220	43.0	0.58 mg/m^3
Deckhand	Xylenes	221	44.3	(0.0035 ppm)
Deckhand	Xylenes	220	43.0	(0.0034 ppm)
Area Air Samples				
On deck	Benzene	225	44.3	<0.002 ppm
On deck	Benzene	224	43.8	<0.002 ppm
In cabin	Benzene	217	43.6	<0.002 ppm
On deck	Benzene soluble fraction	229	449	<0.2 mg/m^3
In cabin	Benzene soluble fraction	215	429	<0.2 mg/m^3
On deck	Carbon Monoxide	235	N/A	Range: 0–4 ppm; Avg: 3 ppm
On deck	Diesel exhaust	230	450	EC: (1.4 µg/m^3); OC: (31 µg/m^3)
On deck	Ethyl benzene	225	44.3	<0.001 ppm
On deck	Ethyl benzene	224	43.8	<0.001 ppm
In cabin	Ethyl benzene	217	43.6	(0.0011 ppm)
On deck	Hydrogen sulfide	235	N/A	0 ppm
On deck	Limonene	225	44.3	(0.0011 ppm)
On deck	Limonene	224	43.8	(0.0013 ppm)
In cabin	Limonene	217	43.6	0.017 ppm
On deck	Mercury	214	41.6	<0.00005 ppm
On deck	Naphthalene	225	44.3	<0.0009 ppm
On deck	Naphthalene	224	43.8	(0.0010 ppm)
In cabin	Naphthalene	217	43.6	(0.0021 ppm)
On deck	Propylene glycol	225	440	<0.002 mg/m^3
On deck	Toluene	225	44.3	(0.0022 ppm)
On deck	Toluene	224	43.8	(0.0016 ppm)
In cabin	Toluene	217	43.6	0.0057 ppm

Table 9. Personal breathing zone and area air concentrations for substances measured on June 16, 2010 on the St. Martin (continued)				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Area Air Samples				
On deck	Total hydrocarbons	225	44.3	0.27 mg/m^3
On deck	Total hydrocarbons	224	43.8	0.30 mg/m^3
In cabin	Total hydrocarbons	217	43.6	0.85 mg/m^3
On deck	Total particulates	229	449	<0.09 mg/m^3
In cabin	Total particulates	215	429	<0.09 mg/m^3
On deck	Xylenes	225	44.3	(0.0029 ppm)
On deck	Xylenes	224	43.8	(0.0032 ppm)
In cabin	Xylenes	217	43.6	(0.0042 ppm)

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 10. Area air concentrations for substances measured on June 20, 2010 on the Miss Carmen				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Area Air Samples				
Rear deck center	Benzene	345	69.0	<0.001 ppm
Rear deck center	Benzene soluble fraction	343	711	<0.07 mg/m^3
Rear deck center	2-Butoxyethanol	304	61.1	< 0.0007 ppm
Rear deck center	Carbon Monoxide	343	N/A	Range: 0–6 ppm; Avg: 4 ppm
Inside cabin	Carbon Monoxide	357	N/A	Range: 0–4 ppm; Avg: 2 ppm
Rear deck center	Diesel exhaust	342	706	EC: 9.1.4 µg/m^3; OC: <10 µg/m^3
Rear deck center	Dipropylene glycol butyl ether	304	61.1	(0.0060 ppm)
Rear deck center	Dipropylene glycol methyl ether	304	61.1	<0.001 ppm
Rear deck center	Ethanol	345	69.0	<0.003 ppm
Rear deck center	Ethyl benzene	345	69.0	<0.0007 ppm
Rear deck center	Limonene	345	69.0	<0.0005 ppm
Rear deck center	Naphthalene	345	69.0	<0.0006 ppm
Rear deck center	Propylene glycol	338	670	<0.001 mg/m^3
Rear deck center	Toluene	345	69.0	<0.0008 ppm
Rear deck center	Total hydrocarbons	345	69.0	(0.0086 mg/m^3)
Rear deck center	Total particulates	343	711	<0.04 mg/m^3
Rear deck center	Xylenes	345	69.0	<0.001 ppm

*N/A = not applicable
†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration
‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Interim Report #4B
Evaluation of Health Effects in Workers Performing Oil Skimming from Floating City #1, Louisiana, June 19–23, 2010

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Introduction

To better assess health symptoms among off-shore response workers, NIOSH investigators traveled to Floating City #1 on June 19–23, 2010 to collect self-administered health symptom surveys from two types of workers involved in off-shore oil skimming: 130 contracted laborers ("responders") who were responsible for oil clean-up work, and more than 300 shrimp boat captains and deck hands, who operated the approximately 125 boats taking part in the operations. Each boat had a captain, one or two deck hands, and one or two responders. The responders were temporarily housed on Floating City #1 located 10 miles northeast of Venice, Louisiana, at the mouth of the Baptiste Collette channel. Each morning and evening, responders were transported to and from the shrimp boats deployed southwest of Floating City #1 by crew boats. Their 12-hour work shifts included travel time as well as time spent on the shrimp boats. Shrimp boat captains and deck hands did not return to Floating City #1 but remained on their boats overnight.

Methods

Surveys, available in English and Spanish, were collected from responders at the end of their workday as they gathered for dinner on the floating city. The following morning, surveys and sealable envelopes were given to the designated leads of responder teams to distribute to captains and deck hands, collect before leaving the work area, and return to NIOSH investigators at the floating city at the end of the day. Workers were asked to report symptoms they experienced while working during response activities.

Results

One hundred twenty-one (93%) of 130 responders and 68 (18%) of 370 eligible captains and deck hands completed the health symptom survey. Demographically, the age and sex distributions of the two groups were similar to each other and to a comparison group of participants (who had been recruited from the Venice Field Operations Branch and the Venice Commanders' Camp and reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals) (See Table 1.).

Reported symptoms, grouped by type, are presented in Table 2, which includes symptoms for responders, captains, and deck hands, and the comparison group of workers. Overall, the most frequently reported symptoms by all groups were upper respiratory irritation and headaches. Scrapes and cuts were the most frequently reported injuries among responders. Although the survey did not have a question about smoking status, NIOSH investigators noted that a large number of the response workers on the floating city were smoking and reported that some ex-smokers said they started smoking again after beginning response work.

Summary

The types of symptoms reported among responders, captains, and deckhands were similar to those reported by response workers who reported no exposures to oil, dispersant, cleaner, or other chemicals. Symptoms related to heat exposure and upper respiratory symptoms were the most frequently reported in all groups. These types of symptoms can be related to a combination of several factors, including heat and humidity, sun exposure, psychosocial stress, and tobacco smoke. We do not believe that the symptoms reported are consistent with exposure to oil, oil constituents, or dispersants.

Although this report focuses on responders, captains, and deckhands involved in oil skimming, we would be remiss not mentioning cigarette smoking. Implementing a no-smoking policy at this late date raises ethical concerns and practical challenges; however, in the future it may be justified in light of the harms resulting from exposure to tobacco smoke and the lack of other avenues of redress for nonsmoking workers. The same legal, practical, and health issues that have driven successful efforts to make other workplaces smoke-free argue in favor of extending similar protection to emergency response workers.

Table 1. Health symptom survey–demographics by group			
	BP Responders	**Captains and Deck Hands**	**Unexposed***
Number of Participants	121	69	103
Age range	18–63	18–65	18–70
Race			
White	26%	55%	40%
Hispanic	28%	4%	29%
Asian	0	26%	9%
Black	37%	10%	19%
Other	5%	3%	3%
Not specified	3%	1%	
Male	98%	99%	96%
Days worked oil spill	1–60	0–60	0–45
Days worked boat	0–60	0–56	0

*Participants were recruited from the Venice Field Operations Branch and the Venice Commanders' Camp. Those who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals were included in this group.

Table 2. Health symptom survey–reported injuries and symptoms

	BP Responders	Captains and Deck Hands	Unexposed*
Number of participants	121	69	103
Injuries			
Scrapes or cuts	12 (10%)	3 (4%)	11 (11%)
Burns by fire	0	0	1 (1%)
Chemical burns	0	0	0
Bad Sunburn	4 (3%)	1 (1%)	8 (8%)
Constitutional symptoms			
Headaches	13 (11%)	9 (13%)	5 (5%)
Feeling faint, dizziness, fatigue or exhaustion, or weakness	5 (4%)	5 (7%)	13 (13%)
Eye and upper respiratory symptoms			
Itchy eyes	5 (4%)	0	5 (5%)
Nose irritation, sinus problems, or sore throat	11 (9%)	10 (14%)	16 (16%)
Metallic taste	0	1 (1%)	0
Lower respiratory symptoms			
Coughing	8 (7%)	4 (6%)	8 (8%)
Trouble breathing, short of breath, chest tightness, wheezing	2 (2%)	2 (3%)	4 (4%)
Cardiovascular symptoms			
Fast heart beat	0	0	1 (1%)
Chest pressure	0	1 (1%)	0
Gastrointestinal symptoms			
Nausea or vomiting	3 (2%)	3 (4%)	3 (3%)
Stomach cramps or diarrhea	5 (4%)	2 (3%)	7 (7%)
Skin symptoms			
Itchy skin, red skin, or rash	5 (4%)	0	8 (8%)
Musculoskeletal symptoms			
Hand, shoulder, or back pain	3 (2%)	2 (3%)	6 (6%)
Psychosocial symptoms			
Feeling worried or stressed	2 (2%)	4 (6%)	4 (4%)
Feeling pressured	1 (1%)	1 (1%)	2 (2%)
Feeling depressed or hopeless	1 (1%)	0	1 (1%)
Feeling short tempered	0	1 (1%)	4 (4%)
Frequent changes in mood	0	1 (1%)	3 (3%)
Heat stress symptoms†			
Any	18 (15%)	12 (17%)	21 (20%)
4 or more symptoms	2 (2%)	1 (1%)	3 (3%)

*Participants were recruited from the Venice Field Operations Branch and the Venice Commanders' Camp. Those who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals were included in this group.

†Headache, dizziness, feeling faint, fatigue or exhaustion, weakness, fast heartbeat, nausea, red skin, or hot and dry skin.

Interim Report #4C
Evaluation of Source Control Vessels Development Driller II and Discoverer Enterprise, June 21–23, 2010

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Introduction

On June 21–23, 2010, NIOSH investigators conducted industrial hygiene surveys and collected self-administered health symptom surveys aboard two vessels located at the site of the Deepwater Horizon Mississippi Canyon (MC) 252 Well No. 1 oil release. This site visit was part of the NIOSH response to a series of Health Hazard Evaluation (HHE) requests that were received from BP concerning workers involved in the Deepwater Horizon response.

Background

MC252 Well No. 1 is located approximately 50 miles southeast of Venice, Louisiana, at a depth of about 5,000 feet. On June 21–23, 2010, the four primary vessels at the Deepwater Horizon MC252 location were two semi-submersible drilling rigs (Development Driller II (DD II) and Development Driller III (DD III)), a drillship (Discoverer Enterprise), and a semi-submersible multipurpose oil field construction and intervention vessel (Q4000). The DD II, DD III, and Discoverer Enterprise are operated by Transocean; the Q4000 is operated by Helix Energy Solutions Group. At the time of the NIOSH evaluation, DD II and DD III were drilling relief wells for the purpose of pumping mud into the blown well to suppress the release of crude oil, followed by concrete to seal the well [BP 2010a]. The Discoverer Enterprise, which was located directly above the blown well, captured oil and gas from the damaged well through a lower marine riser package cap [BP 2010b], which was placed on top of the failed Deepwater Horizon blowout preventer (BOP). Captured oil and gas traveled through the riser insertion tube to the Discoverer Enterprise where gas was separated from the oil, and was burned at the flare boom on the starboard side of the vessel [Deepwater Horizon Unified Command 2010]. Captured oil was stored temporarily aboard the Discoverer Enterprise until it was pumped into an oil tanker. The oil storage capacity of the Discoverer Enterprise is 100,000 barrels [Net Resources International 2010]. The Q4000 draws oil and gas from the choke and kill lines on the BOP. Approximately 9,000 barrels of oil were flared each day by the Q4000. A visible plume of combustion products was generated by the Q4000 flare. The Discoverer Enterprise and Q4000 were generally positioned so that the flare booms were perpendicular to wind direction to carry combustion products away from the vessels.

Development Driller II

The DD II is a semisubmersible drilling unit with an operating water depth of 7,500 feet (ft) and a drilling depth of 37,500 ft (See Figure 1). The main deck width and length are both about 244 ft [Transocean 2010a]. The DD II went into service in 2004 [Transocean 2010b]. The rig contains all equipment and materials for drilling operations including cranes, drilling equipment, hoisting equipment, storage, drill mud conditioning (mixing, cleaning, recirculating) and well-control equipment. The DD II was not involved with oil collection from the damaged BOP and at the time of the NIOSH evaluation was operating in drilling mode, along with DD III. The water surface distance between the DD II and the Discoverer Enterprise was about 2,400 ft; the distance to the DD III was about 2,500 ft. One hundred sixty-seven people were on board the DD II during the NIOSH evaluation. This included 95 Transocean workers, 21 Transocean third party workers, and other personnel with the client (BP) or client third party employers.

Figure 1. GSF Development Driller II. Photo courtesy Transocean Ltd.

Personnel outside of living quarters, offices, and non-hazardous interior work areas were required to wear hard hats, coveralls, gloves, hearing protection, and safety glasses. Personal flotation devices were required during activities presenting a potential for entry into the water. All personnel were required to be fit tested and were equipped with 3M 6000 series half-mask and full-facepiece air purifying respirators equipped with organic vapor/acid gas/P100 cartridges. No oil dispersion agent was used by or stored aboard the DD II. Potential for exposure to crude oil from the MC252 Well No. 1 and dispersion agent was limited to that on the water surrounding the DD II. No activities requiring contact by workers aboard the DD II with crude oil or dispersion agent containing seawater were identified by NIOSH investigators.

Discoverer Enterprise

The Discoverer Enterprise is a deepwater double-hulled dynamically positioned drillship (see Figure 2). The Discoverer Enterprise can perform a range of subsea operations including laying ultra deepwater pipelines and providing extended well testing and storage capabilities. It has an operating water depth of 10,000 ft. and a drilling depth of 35,000 ft. The vessel is 835 ft. long and 125 ft. wide with a height of 418 ft [Transocean 2010c]. The Discoverer Enterprise went into service in 1999 [Transocean 2010b]. The vessel contains dual rotary tables operating under one massive derrick. In addition to containing all the equipment and materials found on drilling rigs, the Discoverer Enterprise can collect and hold about 100,000 barrels of crude oil. At the time of the HHE, the Discoverer Enterprise was located over the damaged MC252 Well BOP and was operating in a recovery and production mode, collecting about 25,000 barrels of oil per day. The vessel had a flare boom located on the starboard side which continuously burned gases coming up with the oil captured from the lower marine riser package cap.

One hundred eighty-six people were on board during the NIOSH evaluation. The largest numbers of workers were with Transocean (93 workers), Schlumberger (22), ART Catering – [quarters operation] (19), Oceaneering – [Remotely Operated Vehicles on the ocean floor] (13), and BP (8).

Figure 2. Discoverer Enterprise. Photo courtesy of Transocean Ltd.

Personnel outside of quarters or non-hazardous work spaces were required to wear hard hats, flame retardant coveralls, gloves, hearing protection, and safety glasses. Because of the high noise level generated by the Discoverer Enterprise flare, double hearing protection (earplugs and ear muffs) was required in designated areas. Personal flotation devices were required during activities presenting a potential for entry into the water. All personnel were required to be fit tested and have in their possession 3M 6000 series half-mask and full-facepiece air purifying respirators equipped with organic vapor/acid gas/P100 cartridges. Workers on deck and in hazardous work spaces on the Discoverer Enterprise were required to carry their respirators and double hearing protection with them. The cartridges used for the air purifying respirators had been changed from organic vapor/P100 to cartridges including acid gas. This modification was implemented after the Q4000 began flaring oil and gas on June 16 [BP 2010c].

Operations aboard the Discoverer Enterprise included transfer of crude oil to oil tankers; operation of remotely operated vehicles (ROVs) near the ocean floor; collection and storage of crude oil; separation of gas from the oil; burning gas at the flare boom; and use of methanol as an anti-freezing agent at depth to reduce icing due to gas hydrate formation. NIOSH investigators were told that no dispersants had been used or stored on the Discoverer Enterprise. Application of dispersion agent was performed on an as-needed basis by other vessels in the area. The dispersion agent had been applied either at the surface or injected at depth. During the NIOSH evaluation on June 23, 2010, the Discoverer Enterprise was transferring about 80,000 barrels of crude oil to the oil tanker Overseas Cascade.

Recovery and production operations aboard the Discoverer Enterprise deviated from routine activities during the NIOSH evaluation on June 23, 2010. At approximately 8 a.m., an alarm was sounded throughout the vessel implementing a muster. All nonessential personnel reported to the galley to be accounted for and to gather in groups by lifeboat assignment. Rising seawater in the riser connecting the Discoverer Enterprise to the damaged well, and through which oil was transported up to the vessel, was occurring. This triggered concern because a decrease in the outflow of seawater from the annulus of the riser at the sea floor may indicate the presence of gas accumulation in the riser and a potential loss of control over the well. Personnel were required to remain at the vessel's muster location until corrective actions were taken to address the immediate concern. Difficulty discerning the cause of rising seawater in the riser prompted implementation of protective measures and an emergency disconnect of the riser from the well. Further investigation disclosed that there was no gas in the riser. A discharge valve on the riser near the collection point at the well had inadvertently been closed resulting in a malfunction. Following the identification and correction of the malfunction, the Discoverer Enterprise riser was reconnected to the well, and resumption of operations and oil collection occurred at approximately 7:50 p.m.

BP Offshore Air Monitoring Activities for Source Control

Monitoring for personal and area airborne concentrations of various contaminants was conducted by Total Safety air monitoring technicians. BP's OFFSHORE Air Monitoring Plan for Source Control, June 11, 2010 revision, was used to direct monitoring activities on the DD II and the Discoverer Enterprise. Two technicians were assigned to the DD II and six to the Discoverer Enterprise. The technicians worked with the vessel operators to select real-time monitoring locations in common work areas and inside crew quarters. In addition, technicians could place additional monitors at other locations or areas of interest (such as the edge of the vessel or by the moon pool [an opening in the hull of the vessel giving access to the water below]) to gain early indications of rising lower explosive limit (LEL) levels [BP 2010d]. Pictures of the moon pools for the DD II and the Discoverer Enterprise are shown in Figures 3 and 4.

Figure 3. DD II lower moon pool.

Figure 4. Discoverer Enterprise moon pool main deck.

Airborne contaminants and atmospheric hazards monitored on the vessels by BP were: volatile organic compounds (VOCs), LEL (calibrated for methane), percent oxygen, hydrogen sulfide (H_2S), carbon monoxide (CO), benzene, sulfur dioxide (SO_2), and particulate matter less than 10 micrometers (µm) aerodynamic diameter (PM10). These latter two contaminants were measured for source control vessels (Discoverer Enterprise and Q4000) that were burning gas or gas and oil as part of containment or production activities. Air monitoring for VOCs was conducted using AreaRAE Steel (Rae Systems, San Jose, California) photo-ionization detectors (PID). An UltraRAE (RAE Systems, San Jose, California) PID monitor, which was specific for benzene, was used when elevated VOC levels were detected. This unit combines an ultraviolet lamp that is energy specific for benzene with a proprietary RAE-Sep™ benzene tube [RAE Systems 2010]. PM10 levels were obtained using stationary or portable Thermo (Thermo Environmental Instruments, Franklin, Massachusetts) or TSI (Shoreview, Minnesota) PM10 data logging monitors. LEL was evaluated with a catalytic bead sensor; electrochemical sensors were used to monitor percent oxygen, H_2S, and CO [BP 2010d].

Personal breathing zone (PBZ) air sampling for benzene and VOCs was conducted using passive organic vapor monitors (OVMs) that were submitted for laboratory analyses. OVM badges were placed on personnel identified as having the highest potential for exposure [BP 2010d]. The majority of environmental and personal exposure measurements collected on the DD II and Discoverer Enterprise and provided to NIOSH investigators were below the lowest of the stepped BP action levels triggering corrective measures. The lowest action levels were 50 parts per million (ppm) for VOCs, 0.5 ppm for benzene, 25 ppm for CO, 5 ppm for H_2S, 1 ppm for SO_2, and 0.35 milligrams per cubic meter of air (mg/m^3)for PM10 [BP 2010e]. Readings at these action levels triggered corrective measures that included using water cannons to break up sheen, relocating nonessential personnel within the vessel, donning respirators, and re-orienting the vessel into the wind. Higher readings that exceeded the top-tier action levels required additional measures, e.g., moving the vessel off location (VOCs ≥ 1,000 ppm; benzene ≥ 10 ppm in living quarters), immediate evacuation of work area (CO ≥ 25 ppm; H_2S ≥ 5 ppm), shutdown of flaring operations (SO_2 ≥ 100 ppm), and donning full-facepiece respirators fitted with organic vapor/acid gas/P100 cartridges (PM10 ≥ 2.5 mg/m^3). Levels of VOCs, benzene, and SO_2 aboard the Discoverer Enterprise were negligible the afternoon of June 23. PM10 values were below the action level except for the measurement at 4:00 p.m., which was recorded at 0.278 mg/m^3 [Ahrenholz 2010a].

Airborne concentration data collected by BP and made available to NIOSH indicated that the contaminants identified in the previous paragraph were generally low compared to OELs. Worker exposure monitoring by BP was obtained primarily through the use of passive dosimeters. Direct reading instrumentation was used for most of the sampling on the vessels. The active integrated sampling conducted by NIOSH investigators sought to evaluate the primary contaminants of concern as well as allow for analysis of additional contaminants that might be present and were compatible with the sampling and analytical methods. Findings from other NIOSH evaluations during the Deepwater Horizon response were used to develop the exposure assessment for these two source vessels. Information provided by BP classifies the oil from MC252 as “light sweet crude” indicating that it is a form of petroleum that contains exceptionally high amounts of the chemicals needed to produce gasoline, kerosene, and high quality crude oil. The “sweet” designation describes sulfur content and that this is a low sulfur crude oil [BP 2010f].

Evaluation

NIOSH investigators conducted PBZ and area air sampling aboard the DD II on June 21 and aboard the Discoverer Enterprise on June 23, 2010. A BP industrial hygienist and a Transocean health, safety, and environment advisor accompanied NIOSH investigators and helped facilitate the NIOSH evaluation. NIOSH investigators and the BP and Transocean representatives were quantitatively fit tested for and issued respiratory protection (half-mask and full facepiece respirators) by a BP contractor at the Houma, Louisiana, heliport before they were permitted to travel out to the vessels. This provided an opportunity to observe the respirator fit testing and individual issue processes in use for all employees and visitors to the offshore vessels.

Both vessels were in continuous operation 24 hours per day. Workers on both vessels worked 12-hour shifts, either 6:00 to 6:00 or 12:00 to 12:00, depending upon whether they were part of the Marine and Maintenance Crews or the Drill and Deck Crews. The work rotation was 2 weeks on and 2 weeks off and NIOSH investigators were informed that the rigs would be changing to a 3 week rotation. NIOSH investigators asked for assistance in identifying workers whose jobs required them to spend more time out on the deck or working in areas of the vessel that had greater potential for exposure to volatile compounds associated with the crude oil.

NIOSH investigators conducted air sampling on these vessels to help characterize exposures of workers who were nearest to the point-of-release where the VOC content of the oil was expected to be greatest. Unlike crews and cleanup workers aboard the Vessels of Opportunity, and cleanup workers onshore, the crews of the DD II and Discoverer Enterprise were performing operations that utilized their usual and standard work skills, PPE, training, and experience, i.e., well drilling aboard the DD II, and storage and processing of crude oil aboard the Discoverer Enterprise. NIOSH investigators surmised that the only source of non-routine occupational exposures aboard these vessels to which the crews might have been exposed was oil on the sea surface that had been released from the blown well.

To evaluate the presence of VOCs, NIOSH industrial hygienists conducted air sampling with (1) multi-sorbent thermal desorption tubes followed by thermal desorption/gas chromatography-mass spectrometry (NIOSH Method 2549), and (2) activated charcoal tubes (NIOSH method 1501 modified; NIOSH method 1550). Thermal desorption tube results were used to select specific VOCs for quantitation in PBZ and area air samples that were collected using charcoal tubes. Sulfinert®-treated thermal desorption tubes were used to assess the presence of sulfur compounds, e.g., sulfides. Other compounds measured in PBZ and area air samples using integrated air sampling techniques included propylene glycol ethers (NIOSH method 1403 modified) and polynuclear aromatic hydrocarbons (PAHs) (NIOSH method 5506), a class of more than 100 compounds that generally occur as complex mixtures. PAHs are formed during the incomplete combustion of coal, oil, gas, and other organic substances.

All samples were kept cold while aboard the vessels and during shipment to the laboratory. All pumps were calibrated before and after each sampling period.

Direct-reading measurements were obtained for CO and H_2S. Two bulk samples of drilling mud from DD II and four bulk samples of crude oil from the Discover Enterprise were obtained for headspace analysis of VOCs. Initial bulk sample analyses were used to identify and confirm the presence of selected contaminants chosen for exposure analyses prior to analyzing for specific compounds on air samples. The bulk sample results will be included in the final NIOSH HHE report. Area sampling for diesel exhaust particulate matter was planned; however, the sampling pump was damaged and could not be used. See Table 1 for a complete listing of sampling and analytical methods used [NIOSH 2010a].

All industrial hygiene equipment used on the vessels had to be certified as intrinsically safe by Underwriters Laboratories, Inc. Because intrinsic safety certification could not be verified for the HOBO® H8 ProSeries data logging temperature and relative humidity monitors typically used by NIOSH investigators [Onset Computer Corporation, Bourne, Massachusetts], these instruments were not used aboard the vessels. Weather data was obtained from the Discoverer Enterprise for June 21 and 23, 2010.

Because of concerns about possible acute health effects among workers, NIOSH industrial hygienists distributed health symptom surveys to workers aboard both vessels. Surveys were provided to workers who agreed to wear NIOSH air sampling equipment and take the survey. Additionally, surveys and return envelopes were given to Transocean and BP management representatives for distribution to crew members aboard both vessels. Completed forms in sealed envelopes were collected by the NIOSH industrial hygienists during the time they were present on each vessel.

Development Driller II

Sampling aboard DD II began at 3:00 p.m. on June 21, 2010, following mandatory in-briefings and orientation for the NIOSH investigators, and an opening conference with Transocean and BP representatives. Individuals who worked outdoors on-deck were identified and were asked to wear sampling pumps and direct-reading instruments. Job titles of sampled workers were roustabout (5), floor hand (1), rotary floor foreman/lead floor hand (1), crane operator (1), and assistant driller (1). PBZ samples were collected for the remainder of the 12:00 p.m. to 12:00 a.m. shift (437 to 491 minute sampling period). Area samples were collected at the lower moon pool, wire line deck, well test, and at a pipe manifold outside near the drill shack.

Discoverer Enterprise

Full-shift PBZ air sampling was conducted throughout the 6:00 a.m. to 6:00 p.m. shift on June 23, 2010. Individuals who worked outdoors were identified and asked to wear sampling pumps and direct-reading instruments. The job titles of sampled workers were well-test field technician (1), floor hand (2), Chief Mate (1), fire technician (2), Superintendent of ROVs (1), electrician (1), motorman (1), and air monitoring technician (1). The full-shift sample for the floor hand was collected on two individuals: one was sampled from 6:00 a.m. until the end of the shift at 12:00 p.m., and the other was sampled from 12:00 p.m. on the following shift; thus, the floor hand results are reported in half-shift segments for each of the two floor hands. The duration of the PBZ samples was 304 to 771 minutes. Area samples were collected at the moon pool and on the well test deck.

The normal work routine was interrupted at 8:00 a.m. due to indications that flammable gas might be entering the riser from the blown well. Non-essential personnel, including some sampled workers, mustered in the galley for about 1 hour before being told to return to normal duties. The drillship was disconnected from the blown well and was moved about 200 ft from its normal location directly above the well, which caused flaring to cease on the Discoverer Enterprise. Transocean and BP representatives noted that past experience indicated airborne VOC concentrations could increase approximately 3 hours after disconnecting from the well when a larger volume of crude oil could reach the surface. The ship was reconnected to the well, and resumed capturing oil and gas at approximately 7:50 p.m.

Results and Discussion

Table 2 contains a summary of the relevant occupational exposure limits (OELs) to which results were compared. Note that OELs have not been established for some of the contaminants measured during this HHE. The lack of an OEL does not necessarily mean that a substance does not have toxic properties or interactive effects with other contaminants.

VOC screening samples were collected at the moon pools on both vessels using three-bed thermal desorption tubes and two-bed Sulfinert-treated thermal desorption tubes. Low concentrations of VOCs were detected on both vessels. The most abundant compounds identified were C_{10}–C_{16} aliphatic hydrocarbons. Other compounds detected in screening samples included ethylene glycol, 2-butoxyethanol, benzaldehyde, and phenol. Blank Sulfinert-treated tubes contained trace amounts of several contaminants. The ambient temperature and relative humidity (RH) was 84°F and 82% RH on June 21, and 85°F and 82% RH on June 23, 2010.

Development Driller II

Charcoal tube air samples obtained on DD II were quantitatively analyzed for benzene, ethyl benzene, toluene, xylenes, limonene, naphthalene, dipropylene glycol butyl ether, dipropylene glycol methyl ether, and total hydrocarbons (as n-hexane). PBZ results are shown in Table 3 for four workers identified by letters A through D. Area sample results are shown on the last page of Table 3. Airborne concentrations of all sampled compounds were well below relevant OELs.

Volatile Organic Compounds
Benzene, ethyl benzene, and naphthalene were not detected in PBZ or area air samples collected on charcoal tubes on the DD II. Toluene was detected below the minimum quantifiable concentration (MQC) in an area air sample on the wire line deck, but was not detected in any of the PBZ air samples. Xylenes were present below the MQC in two PBZ air samples and in the area air sample on the wire line deck. Limonene was detected below the MQC in two PBZ air samples and was not detected above the minimum detectable concentration (MDC) in the other two PBZ air samples. Limonene was present in a quantifiable concentration (0.032 ppm) on the wire line deck, but was not detected in the area air sample at the pipe manifold. Limonene was below the MQC in two PBZ air samples, and not detected in the other two PBZ air samples. Total hydrocarbons (THCs) were quantified in all PBZ and area air samples. PBZ air samples for THCs ranged from 0.5 to 1.1 mg/m^3; the two area air samples had concentrations of 0.16 and 9.3 mg/m^3. The highest THC concentration was measured on the wire line deck where several other area samples found detectable or quantifiable concentrations of other airborne compounds.

2-Butoxyethanol and Dipropylene Glycol Ethers
NIOSH laboratory support analyzed for dipropylene glycol butyl ether, a component in COREXIT® EC9500A [Nalco 2010], the dispersant that was injected consistently underwater near the point-of-release by a nearby support vessel, Skandi Neptune, during the June 21–23, 2010, period. Dispersant was applied at the surface only on June 21, 2010, from 4:00 a.m. to 9:00 a.m. [Ahrenholz 2010b]. Some disruptions in dispersant application occurred at 9:30 a.m., 1:00 p.m., and between 5:00 p.m. and 7:00 p.m. No dispersants were used or applied by workers aboard the DD II or the Discoverer Enterprise. 2-butoxyethanol was identified in the thermal desorption tube screening samples and was subsequently quantified in some of the air samples.

2-butoxyethanol concentrations in PBZ air samples ranged from 0.029 to 0.28 ppm. The highest concentration was quantified in the sample collected on the rotary foreman while working on the rig floor. A review of drilling mud component material safety data sheets did not disclose any 2-butoxyethanol containing materials. The area air sample obtained on the wire line deck indicated 0.30 ppm; the area sample nearest to the ocean surface at the lower moon pool was below the MQC. Neither dipropylene glycol butyl ether nor dipropylene glycol methyl ether were detected in any of the PBZ or area air samples.

Polynuclear Aromatic Hydrocarbons
PBZ air samples were obtained for five workers (labeled as E through I in Table 3). No area air samples were collected. Total PAHs were calculated as the sum of the peaks for the 17 individual compounds shown in Table 3. Total PAHs values were field blank corrected. The total PAHs for each sample were quantitated as naphthalene.

Total PAHs in samples collected aboard DD II ranged from 0.0074 to 0.0096 mg/m^3 of air. Naphthalene (range: 0.00011–0.00094 ppm), phenanthrene (range: 0.0037–0.0074 mg/m^3), and pyrene (range: 0.00046–0.001 mg/m^3), were quantified in all five PBZ samples.

Fluoranthracene was quantified in the sample collected for worker G; fluorene was quantified in samples collected for workers H and I. Acenaphthene, acenapthylene, and fluoranthracene were below the MQC in samples collected for worker I; acenapthylene was detected below the MQC for worker F. Fluorene was present below the MQC for worker G.

Carbon Monoxide and Hydrogen Sulfide
The average CO concentration inside and outside the shack on the wire line deck was 1 ppm (range: 0–6 ppm). Hydrogen sulfide was not detected in the breathing zones of the four workers who wore monitors (workers E, F, G, and H), nor was H_2S detected in the single area air sample collected at the pipe manifold.

Discoverer Enterprise

Charcoal tube air samples obtained on the Discoverer Enterprise were quantitatively analyzed for the same compounds as described above for DD II, i.e., benzene, ethyl benzene, toluene, xylenes, limonene, naphthalene, dipropylene glycol butyl ether, dipropylene glycol methyl ether and total hydrocarbons (as n-hexane). PBZ results for charcoal tube samples are shown in Table 4 for five workers (A through E). Area air samples were obtained at the well test deck and the moon pool. Area air sample results are shown on the last page of Table 4. Airborne concentrations of all sampled compounds were well below relevant OELs for samples collected aboard the Discoverer Enterprise.

Volatile Organic Compounds
Benzene, ethyl benzene, and naphthalene were not detected in PBZ or area air samples collected on charcoal tubes on the Discoverer Enterprise. Toluene and xylenes were detected below the MQC in the PBZ air sample collected on the air monitoring technician (worker B), but were below the MDC in the other four PBZ air samples as well as in the two area air samples. Limonene was quantified in three PBZ air samples (workers A, B, and C), but was not detected in the other two personal samples. Limonene was detected below the MQC on the well test deck; limonene was not detected at the moon pool. THCs were quantified in all PBZ air samples on workers B through E, and area air samples. THCs in PBZ air samples ranged from 0.08 to 0.42 mg/m^3; area air samples indicated THC concentrations of 0.13 at the well test deck and 0.080 mg/m^3 at the moon pool.

2-Butoxyethanol and Dipropylene Glycol Ethers
Quantifiable concentrations of 2-butoxyethanol were measured in one PBZ air sample and in the area air sample collected on the well test deck. 2 butoxyethanol in the other four PBZ air samples and in the area air sample at the moon pool was below the MQC. Dipropylene glycol butyl ether was detected below the MQC in PBZ air samples for workers B and C. Dipropylene glycol ethers were not detected in the other samples.

Polynuclear Aromatic Hydrocarbons
PBZ air samples were obtained for five workers (labeled F through J in Table 4). No PAH area air samples were collected. Total PAHs were calculated as the sum of all peaks present in the sample. The total PAHs for each sample were quantitated as naphthalene.

Total PAHs in samples collected aboard Discoverer Enterprise ranged from 0.0048 to 0.020 mg/m^3. Naphthalene (range: 0.00026–0.11 ppm), phenanthrene (range: 0.0025–0.012 mg/m^3), and pyrene (range: 0.00050–0.0041 mg/m^3), were quantified in all five PBZ air samples.

Fluorene was quantified in the sample collected for worker G, and was detected below the MQC in the other four PBZ air samples. Acenapthylene was detected below the MQC in three PBZ air samples, and chrysene was found below the MQC in one PBZ air sample.

Carbon Monoxide and Hydrogen Sulfide
The average CO concentration displayed by the meter worn by worker I and the meter on the well test deck was 0 ppm (range, 0–5 ppm). Hydrogen sulfide was not detected in the breathing zones of the four workers who wore monitors (workers B, D, E, and J).

Observations Applicable to Both Vessels

NIOSH investigators noted two issues related to the respiratory protection program and immediately discussed their concerns with the BP and Transocean representatives accompanying them. One issue was with the respirator fit testing and issuance procedures at the Houma, Louisiana, heliport at the time of the NIOSH evaluation. The use of only one manufacturer's line of respirators to fit all personnel presented the possibility that proper respirator fit might not be attained for some workers. Another issue was the subsequent observation that a small number of workers on the vessels had facial hair that could interfere with the proper seal of a respirator. Needed corrective actions were immediately noted and corrective actions reportedly initiated by BP and Transocean representatives.

Smoking was prohibited aboard both vessels with the exception of one designated outdoor location on the Discoverer Enterprise. The potential for interference from tobacco smoke with the NIOSH exposure monitoring is not considered a problem. The use of smokeless tobacco by some workers was observed but would not affect exposure results.

Health Symptom Surveys

Twenty-eight persons on the DDII and thirty-four on the Discoverer Enterprise completed the health symptom survey. Demographically, workers on these two vessels were similar (Table 5). Reported symptoms, grouped by type, are presented in Table 6. This table includes symptoms for workers surveyed on the two vessels and a comparison group of workers recruited at the Venice Field

Operations Branch and the Venice Commanders' Camp who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals.

Overall, workers aboard the DDII reported a wider variety and a higher number of health symptoms than workers from either the Discoverer Enterprise or the comparison group. Injuries and cardiovascular symptoms were very low aboard both vessels. Headache and heat stress symptoms were reported among workers on both vessels, while symptoms of feeling worried, stressed, and pressured were highest among workers aboard the DDII. Thirty-two percent of DDII workers reported feeling worried or stressed compared to 6% on the Discoverer Enterprise and 4% in the comparison group.

Summary

Exposure assessments at the source provided an opportunity to evaluate potential contaminants associated with the oil release. Work activities on the DD II and the Discoverer Enterprise involved operations typical of offshore oil well development and oil collection but were occurring in the context of the explosion that killed 11 workers and released an unprecedented amount of oil into the Gulf of Mexico.

NIOSH investigators and others involved in the Deepwater Horizon response postulated that workers on the source control vessels had the greatest potential for exposure to contaminants from the oil. Their proximity to the source made them the most likely group to be exposed to the volatile crude oil constituents released to the atmosphere above the damaged well. Additionally, conditions on the vessels providing enclosures or conduits for chemical vapors, such as the moon pool of the Discoverer Enterprise, could provide opportunities for increased exposure. Flares on two source vessels, one on the Discoverer Enterprise and the other on the Q4000, created possible exposures to combustion by-products. Potential for worker exposure to dispersants, however, was considered to be to be less likely than for other response workers.

Airborne concentrations for all contaminants evaluated on the DD II and the Discoverer Enterprise were well below (< 10% and often substantially less than 10% of) applicable OELs. Although the number of workers sampled was relatively small, samples were collected from those thought to have the greatest exposure potential, i.e., working on open decks and directly involved with relief well drilling (DD II) or collecting oil coming through the riser from the damaged well (Discoverer Enterprise). Although NIOSH investigators were told that VOC levels might increase as a result of the non-routine events on the day of their exposure monitoring, no such increase was evident in the sampling results.

PBZ air sampling results for nine workers on the DD II resulted in 69% (90) of the 130 analyses for specific contaminants to be below detectable levels. Samples with detectable contamination had results ranging from below the minimum quantifiable concentration to an amount that was quantifiable but very low. CO and H_2S concentrations were negligible (0–6 ppm CO) or zero (CO and H_2S). The four sets of area samples reflected the same proportion of nondetectable concentrations.

PBZ air sampling results for 10 workers on the Discoverer Enterprise resulted in 67% (94) of the 140 analyses for specific contaminants to be below detectable levels. Samples with detectable contamination had results ranging from below the minimum quantifiable concentration to a concentration that was quantifiable but very low. CO and H_2S values were negligible (0–6 ppm for CO) or zero (CO and H_2S). In the two sets of area samples, 75% of the 20 contaminant-specific analyses were below detectable levels.

One issue to consider in interpreting these findings is the fact that the results are compared to OELs unadjusted for actual work schedules. The source control vessels operated on 12 hour, 7 day per week schedules with workers working 2 or 3 week-long rotations. Downward adjustment of the OELs, however, would not change the findings or determination for the days monitored due to the fact that all exposures were very low.

The NIOSH evaluation did not identify overexposures to contaminants that would necessitate routine wearing of respiratory protection; however, the immediate availability of respiratory protection is appropriate in this work environment because of the potential for an upset in operations, uncharacterized chemical releases, and sporadic releases of chemicals that may approach targeted action levels. Continuous on-board monitoring for contaminants of concern is a reasonable strategy for this situation.

Workers aboard the DD II reported more symptoms, particularly psychosocial symptoms, than workers aboard the Discoverer Enterprise and response workers not working on vessels or with exposure to chemical hazards. In light of the lack of evidence for significant chemical exposures, variations in rates of physical symptoms may be related to other factors (occupational and non-occupational) or may represent random variation. Because heat stress symptoms were reported aboard both vessels, BP should maintain the Deepwater Horizon Off-shore Clean-up Task Force Heat Stress Management Plan, with re-evaluation and modification as necessary based on conditions.

Thirteen workers aboard the DD II reported feeling worried, stressed, or pressured. Many contributing factors, both occupational and non-occupational, may have led to these responses. To determine the specific factors for these work stress factors would require further study. At the time of this evaluation, oil was still leaking onto the Gulf, resulting in scrutiny and pressure to complete the relief wells as quickly as possible.

Recommendations

Although the data collected on the days of the NIOSH evaluation did not indicate the need for mandatory, routine respiratory protection, the practice of having respirators immediately available for workers during uncontrolled situations or during operations where continuous area monitoring indicates rising exposure levels should continue.

The conduct of respiratory protection fit testing and issuance of air purifying respirators at the Houma, Louisiana, heliport, as well as their adherence to BP respiratory protection program requirements, needs to be reassessed and corrections implemented. The ability to adequately protect workers with one respirator line from one manufacturer is a questionable practice [OSHA 2004]. Identification and selection of an alternate model of air purifying respirator is needed. Although this does present challenges regarding respirator inventory and use, all workers need to be provided effective respiratory protection.

The respirator fit testing process also provides a teachable moment for workers that should be better utilized. Information to be covered should include limitations of respiratory protection, proper donning and doffing procedures, indicators of the need for changing respirator cartridges, and proper storage and cleaning of respirators. Restrictions concerning facial hair and the ability to use air purifying respirators should be re-iterated to all workers where the potential to use respiratory protection is required. Although a worker may be clean-shaven on the day he reports to a source vessel, he needs to maintain this status over the course of the 2–3 week work rotation aboard the vessel.

The appropriateness of applying unadjusted OELs to worker exposures obtained for 12 hour, 7 day per week work schedules should be reevaluated for these operations. Consideration should be given to identifying the appropriate OELs for comparing full shift exposures and for deriving action levels that trigger additional exposure reduction measures [NIOSH 2010b]. Transition from the current 2 week rotation to a 3 week rotation may have the potential to further complicate contaminant exposures. Ross [2009] in his review of offshore industry shift work also notes that there may be a potential for increased severity of injuries once shifts are extended beyond 12 hours in duration or tours of duty extended beyond the UK sector practice of 2 weeks.

Because heat stress symptoms were reported aboard both vessels, BP should maintain the Deepwater Horizon Off-shore Clean-up Task Force Heat Stress Management Plan, with re-evaluation and modification as necessary based on conditions.

BP and its contractors might consider a special emphasis follow-up with regard to EAP services for the workers on the source control, given our survey results regarding stress on the DDII. We are aware that BP employees always have access to BP's EAP Hotline, and confidential counseling services whether employees are on or off-rotation.

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Table 1. Analytical methods used aboard Development Driller II and Discoverer Enterprise, June 21–23, 2010	
Analyte	**Method**
Benzene	NMAM† 1501‡
Carbon monoxide	Direct reading—GasAlert CO Extreme, BW Technologies Ltd., Calgary, Canada
Ethyl benzene	NMAM 1501‡
Glycol ethers (2-Butoxyethanol, Dipropylene glycol butyl ether, Dipropylene glycol methyl ether)	NMAM 1403‡
Hydrogen sulfide	Direct reading—GasAlert H_2S Extreme, BW Technologies Ltd., Calgary, Canada
Limonene	NMAM 1501‡
Naphthalene	NMAM 1501‡
Polynuclear aromatic hydrocarbons	NMAM 5506
Toluene	NMAM 1501‡
Total hydrocarbons	NMAM 1501‡
Volatile organic compounds (Screening)	NMAM 2549
Xylenes, total	NMAM 1501‡

†National Institute for Occupational Safety and Health (NIOSH) Manual of Analytical Methods [NIOSH 2010a]
‡Analysis for selected volatile organic compounds by an adaptation of the method

Table 2. Occupational exposure limits for substances evaluated aboard Development Driller II and Discoverer Enterprise, June 21–23, 2010

Chemical	NIOSH REL[a]	OSHA PEL[b]	ACGIH TLV[c]	AIHA WEEL[d]
Benzene	0.1 ppm TWA[e] 1 ppm STEL[f]	1 ppm TWA 5 ppm STEL 0.5 ppm Action Level	0.5 ppm TWA 2.5 ppm STEL	N/A[g]
2-Butoxyethanol	5 ppm TWA	50 ppm TWA	20 ppm TWA	N/A
Carbon monoxide	35 ppm TWA 200 ppm Ceiling	50 ppm TWA	25 ppm TWA	N/A
Dipropylene glycol butyl ether	N/A	N/A	N/A	N/A
Dipropylene glycol methyl ether	100 ppm TWA 150 ppm STEL	100 ppm TWA	100 ppm TWA 150 ppm STEL	N/A
Ethyl benzene	100 ppm TWA 125 ppm STEL	100 ppm TWA	100 ppm TWA[h] 125 ppm STEL	N/A
Hydrogen sulfide	10 ppm Ceiling (10 min max)	20 ppm Ceiling[i]	1 ppm TWA 5 ppm STEL	N/A
Limonene	N/A	N/A	N/A	30 ppm TWA
Naphthalene	10 ppm TWA 15 ppm STEL	10 ppm TWA	10 ppm TWA 15 ppm STEL	N/A
Polynuclear Aromatic Hydrocarbons	N/A[j]	N/A[j]	N/A[j]	N/A
Total hydrocarbons	350 mg/m^3 TWA 1800 mg/m^3 Ceiling (Petroleum distillates)	2000 mg/m^3 TWA (Petroleum distillates as naphtha)	200 mg/m^3 TWA (Kerosene as total hydrocarbon vapor)	N/A
Toluene	100 ppm TWA 150 ppm STEL	200 ppm TWA 300 ppm Ceiling 500 ppm Peak (10 min max)	20 ppm TWA	N/A
Xylenes	100 ppm TWA 150 ppm STEL	100 ppm TWA	100 ppm TWA 150 ppm STEL	N/A

[a]National Institute for Occupational Safety and Health (NIOSH) recommended exposure limit (REL) [NIOSH 2005]
[b]Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) [29 CFR 1910]
[c]American Conference of Governmental Industrial Hygienists® (ACGIH) threshold limit value® (TLV) [ACGIH 2010]
[d]American Industrial Hygiene Association (AIHA) Workplace Environmental Exposure Level (WEEL) [AIHA 2010]
[e]TWA = time weighted average
[f]STEL = short term exposure limit
[g]N/A = not applicable
[h]Proposed to be changed to 20 ppm TWA and STEL eliminated [ACGIH 2010]
[i]Exposures shall not exceed with the following exception: if no other measurable exposure occurs during the 8-hour work shift, exposures may exceed 20 ppm, but not more than 50 ppm (peak), for a single time period up to 10 minutes
[j]With the exception of naphthalene, OELs are not available for the individual PAHs measured in this evaluation.

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker A				
Roustabout, Main Deck	Benzene	442	45.5	<0.001 ppm
Roustabout, Main Deck	2-Butoxyethanol	445	86.3	0.065 ppm
Roustabout, Main Deck	Dipropylene glycol butyl ether	445	86.3	<0.0007 ppm
Roustabout, Main Deck	Dipropylene glycol methyl ether	445	86.3	<0.0004 ppm
Roustabout, Main Deck	Ethyl benzene	442	45.5	<0.001 ppm
Roustabout, Main Deck	Limonene	442	45.5	(0.0010 ppm)
Roustabout, Main Deck	Naphthalene	442	45.5	<0.0008 ppm
Roustabout, Main Deck	Toluene	442	45.5	<0.001 ppm
Roustabout, Main Deck	Total hydrocarbons	442	45.5	0.66 mg/m^3
Roustabout, Main Deck	Xylenes	442	45.5	(0.0031 ppm)
Personal Breathing Zone Air Samples—Worker B				
Rotary Foreman/Lead Floor Hand, Rig Floor	Benzene	457	48.5	<0.001 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	2-Butoxyethanol	460	48.0	0.28 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Dipropylene glycol butyl ether	460	48.0	<0.001 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Dipropylene glycol methyl ether	460	48.0	<0.0007 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Ethyl benzene	457	48.5	<0.0009 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Limonene	457	48.5	<0.0007 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Naphthalene	457	48.5	<0.0008 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Toluene	457	48.5	<0.001 ppm
Rotary Foreman/Lead Floor Hand, Rig Floor	Total hydrocarbons	457	48.5	1.1 mg/m^3
Rotary Foreman/Lead Floor Hand, Rig Floor	Xylenes	457	48.5	<0.002 ppm

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker C				
Roustabout, Main Deck	Benzene	451	47.5	<0.001 ppm
Roustabout, Main Deck	2-Butoxyethanol	450	47.9	0.082 ppm
Roustabout, Main Deck	Dipropylene glycol butyl ether	450	47.9	<0.001 ppm
Roustabout, Main Deck	Dipropylene glycol methyl ether	450	47.9	<0.0007 ppm
Roustabout, Main Deck	Ethyl benzene	451	47.5	<0.001 ppm
Roustabout, Main Deck	Limonene	451	47.5	<0.0008 ppm
Roustabout, Main Deck	Naphthalene	451	47.5	<0.0008 ppm
Roustabout, Main Deck	Toluene	451	47.5	<0.001 ppm
Roustabout, Main Deck	Total hydrocarbons	451	47.5	0.50 mg/m^3
Roustabout, Main Deck	Xylenes	451	47.5	(0.0026 ppm)
Personal Breathing Zone Air Samples—Worker D				
Floor Hand, Rig Floor	Benzene	461	48.8	<0.001 ppm
Floor Hand, Rig Floor	2-Butoxyethanol	461	48.3	0.029 ppm
Floor Hand, Rig Floor	Dipropylene glycol butyl ether	461	48.3	<0.001 ppm
Floor Hand, Rig Floor	Dipropylene glycol methyl ether	461	48.3	<0.0007 ppm
Floor Hand, Rig Floor	Ethyl benzene	461	48.8	<0.0009 ppm
Floor Hand, Rig Floor	Limonene	461	48.8	(0.015 ppm)
Floor Hand, Rig Floor	Naphthalene	461	48.8	<0.0008 ppm
Floor Hand, Rig Floor	Toluene	461	48.8	<0.001 ppm
Floor Hand, Rig Floor	Total hydrocarbons	461	48.8	1.1 mg/m^3
Floor Hand, Rig Floor	Xylenes	461	48.8	<0.002 ppm
Personal Breathing Zone Air Samples—Worker E				
Roustabout, Main Deck	Acenaphthene	468	935	<0.0001 mg/m^3
Roustabout	Acenapthylene	468	935	<0.0001 mg/m^3
Roustabout	Anthracene	468	935	<0.0001 mg/m^3
Roustabout	Benzo(a)anthracene	468	935	<0.0002 mg/m^3
Roustabout	Benzo(a)pyrene	468	935	<0.0003 mg/m^3
Roustabout	Benzo(b)fluoranthene	468	935	<0.0001 mg/m^3
Roustabout	Benzo(e)pyrene	468	935	<0.0002 mg/m^3
Roustabout	Benzo(g,h,i)perylene	468	935	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(k)fluoranthene	468	935	<0.0001 mg/m^3
Roustabout, Main Deck	Chrysene	468	935	<0.0001 mg/m^3
Roustabout, Main Deck	Dibenzo(a,h)anthracene	468	935	<0.0001 mg/m^3
Roustabout, Main Deck	Fluoranthracene	468	935	<0.0001 mg/m^3
Roustabout, Main Deck	Fluorene	468	935	<0.0001 mg/m^3
Roustabout, Main Deck	Hydrogen sulfide	493	N/A	0 ppm
Roustabout, Main Deck	Indeno(1,2,3-cd)pyrene	468	935	<0.0002 mg/m^3
Roustabout, Main Deck	Naphthalene	468	935	0.000094 ppm

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII (continued)

Activity/Location	**Substance**	**Sampling Information*** **Time (min)**	**Sampling Information*** **Volume (Liters)**	**Sample Concentration†‡**
Personal Breathing Zone Air Samples—Worker E (continued)				
Roustabout, Main Deck	Phenanthrene	468	935	0.0042 mg/m^3
Roustabout, Main Deck	Pyrene	468	935	0.00046 mg/m^3
Roustabout, Main Deck	Total PAHs	468	935	0.0074 mg/m^3
Personal Breathing Zone Air Samples—Worker F				
Crane Operator, Starboard Crane	Acenaphthene	437	875	<0.00006 mg/m^3
Crane Operator, Starboard Crane	Acenapthylene	437	875	(0.00014 mg/m^3)
Crane Operator, Starboard Crane	Anthracene	437	875	<0.00006 mg/m^3
Crane Operator, Starboard Crane	Benzo(a)anthracene	437	875	<0.00009 mg/m^3
Crane Operator, Starboard Crane	Benzo(a)pyrene	437	875	<0.0002 mg/m^3
Crane Operator, Starboard Crane	Benzo(b)fluoranthene	437	875	<0.00006 mg/m^3
Crane Operator, Starboard Crane	Benzo(e)pyrene	437	875	<0.0001 mg/m^3
Crane Operator, Starboard Crane	Benzo(g,h,i)perylene	437	875	<0.0001 mg/m^3
Crane Operator, Starboard Crane	Benzo(k)fluoranthene	437	875	<0.00007 mg/m^3
Crane Operator, Starboard Crane	Chrysene	437	875	<0.00009 mg/m^3
Crane Operator, Starboard Crane	Dibenzo(a,h)anthracene	437	875	<0.00007 mg/m^3
Crane Operator, Starboard Crane	Fluoranthracene	437	875	<0.00007 mg/m^3
Crane Operator, Starboard Crane	Fluorene	437	875	0.00027 mg/m^3
Crane Operator, Starboard Crane	Hydrogen sulfide	487	N/A	0 ppm
Crane Operator, Starboard Crane	Indeno(1,2,3-cd)pyrene	437	875	<0.0001 mg/m^3
Crane Operator, Starboard Crane	Naphthalene	437	875	0.00013 ppm
Crane Operator, Starboard Crane	Phenanthrene	437	875	0.0037 mg/m^3
Crane Operator, Starboard Crane	Pyrene	437	875	0.00053 mg/m^3
Crane Operator, Starboard Crane	Total PAHs	437	875	0.0081 mg/m^3

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII (continued)

Activity/Location	Substance	Sampling Information* Time (min)	Sampling Information* Volume (Liters)	Sample Concentration†‡
Personal Breathing Zone Air Samples—Worker G				
Roustabout, Main Deck	Acenaphthene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Acenapthylene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Anthracene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Benzo(a)anthracene	444	879	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(a)pyrene	444	879	<0.0003 mg/m^3
Roustabout, Main Deck	Benzo(b)fluoranthene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Benzo(e)pyrene	444	879	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(g,h,i)perylene	444	879	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(k)fluoranthene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Chrysene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Dibenzo(a,h)anthracene	444	879	<0.0001 mg/m^3
Roustabout, Main Deck	Fluoranthracene	444	879	0.00014 mg/m^3
Roustabout, Main Deck	Fluorene	444	879	(0.00017 mg/m^3)
Roustabout, Main Deck	Hydrogen sulfide	473	N/A	0 ppm
Roustabout, Main Deck	Indeno(1,2,3-cd)pyrene	444	879	<0.0002 mg/m^3
Roustabout, Main Deck	Naphthalene	444	879	0.00014 ppm
Roustabout, Main Deck	Phenanthrene	444	879	0.0043 mg/m^3
Roustabout, Main Deck	Pyrene	444	879	0.0010 mg/m^3
Roustabout, Main Deck	Total PAHs	444	879	0.0096 mg/m^3
Personal Breathing Zone Air Samples—Worker H				
Roustabout, Main Deck	Acenaphthene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Acenapthylene	491	972	<0.00009 mg/m^3
Roustabout, Main Deck	Anthracene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Benzo(a)anthracene	491	972	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(a)pyrene	491	972	<0.0003 mg/m^3
Roustabout, Main Deck	Benzo(b)fluoranthene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Benzo(e)pyrene	491	972	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(g,h,i)perylene	491	972	<0.0002 mg/m^3
Roustabout, Main Deck	Benzo(k)fluoranthene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Chrysene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Dibenzo(a,h)anthracene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Fluoranthracene	491	972	<0.0001 mg/m^3
Roustabout, Main Deck	Fluorene	491	972	0.00039 mg/m^3
Roustabout, Main Deck	Hydrogen Sulfide	508	N/A	0 ppm
Roustabout, Main Deck	Indeno(1,2,3-cd)pyrene	491	972	<0.0002 mg/m^3
Roustabout, Main Deck	Naphthalene	491	972	0.00011 ppm
Roustabout, Main Deck	Phenanthrene	491	972	0.0074 mg/m^3
Roustabout, Main Deck	Pyrene	491	972	0.00084 mg/m^3
Roustabout, Main Deck	Total PAHs	491	972	0.0083 mg/m^3
Personal Breathing Zone Air Samples—Worker I				
Assistant Driller/Rig Floor	Acenaphthene	468	931	(0.00015 mg/m^3)
Assistant Driller/Rig Floor	Acenapthylene	468	931	(0.00014 mg/m^3)

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII (continued)				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Personal Breathing Zone Air Samples—Worker I (continued)				
Assistant Driller/Rig Floor	Anthracene	468	931	<0.0001 mg/m^3
Assistant Driller/Rig Floor	Benzo(a)anthracene	468	931	<0.0002 mg/m^3
Assistant Driller/Rig Floor	Benzo(a)pyrene	468	931	<0.0003 mg/m^3
Assistant Driller/Rig Floor	Benzo(b)fluoranthene	468	931	<0.0001 mg/m^3
Assistant Driller/Rig Floor	Benzo(e)pyrene	468	931	<0.0002 mg/m^3
Assistant Driller/Rig Floor	Benzo(g,h,i)perylene	468	931	<0.0002 mg/m^3
Assistant Driller/Rig Floor	Benzo(k)fluoranthene	468	931	<0.0001 mg/m^3
Assistant Driller/Rig Floor	Chrysene	468	931	<0.0001 mg/m^3
Assistant Driller/Rig Floor	Dibenzo(a,h)anthracene	468	931	<0.0001 mg/m^3
Assistant Driller/Rig Floor	Fluoranthracene	468	931	(0.00013 mg/m^3)
Assistant Driller/Rig Floor	Fluorene	468	931	0.00019 mg/m^3
Assistant Driller/Rig Floor	Indeno(1,2,3-cd)pyrene	468	931	<0.0002 mg/m^3
Assistant Driller/Rig Floor	Naphthalene	468	931	0.00021 ppm
Assistant Driller/Rig Floor	Phenanthrene	468	931	0.0041 mg/m^3
Assistant Driller/Rig Floor	Pyrene	468	931	0.00069 mg/m^3
Assistant Driller/Rig Floor	Total PAHs	468	931	0.0088 mg/m^3
Area Air Samples				
Wire Line Deck 4th Level	Benzene	467	49.3	<0.001 ppm
Pipe Manifold	Benzene	372	19.8	<0.003 ppm
Wire Line Deck 4th Level	2-Butoxyethanol	470	49.4	0.30 ppm
Lower Moon Pool Fore Side	2-Butoxyethanol	183	9.74	(0.0062 ppm)
Rig Level 4 Wire Line – Outside Shack Door	Carbon Monoxide	460	N/A	Range: 0–6 ppm; Avg: 1 ppm
Rig Level 4 Wire Line – Inside Shack Over Workstation	Carbon Monoxide	465	N/A	Range: 0–6 ppm; Avg: 1 ppm
Wire Line Deck 4th Level	Dipropylene glycol butyl ether	470	49.4	<0.001 ppm
Lower Moon Pool Fore Side	Dipropylene glycol butyl ether	183	9.74	<0.007 ppm
Wire Line Deck 4th Level	Dipropylene glycol methyl ether	470	49.4	<0.0007 ppm
Lower Moon Pool Fore Side	Dipropylene glycol methyl ether	183	9.74	<0.003 ppm
Wire Line Deck 4th Level	Ethyl benzene	467	49.3	<0.0009 ppm
Pipe Manifold	Ethyl benzene	372	19.8	<0.002 ppm
Pipe Manifold	Hydrogen sulfide	411	N/A	0 ppm
Wire Line Deck 4th Level	Limonene	467	49.3	0.032
Pipe Manifold	Limonene	372	19.8	<0.002 ppm

Table 3. Personal breathing zone and area air concentrations for substances measured on June 21, 2010 on the DDII (continued)				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Area Air Samples (continued)				
Wire Line Deck 4th Level	Naphthalene	467	49.3	<0.0008 ppm
Pipe Manifold	Naphthalene	372	19.8	<0.002 ppm
Wire Line Deck 4th Level	Toluene	467	49.3	(0.0012 ppm)
Pipe Manifold	Toluene	372	19.8	<0.003 ppm
Wire Line Deck 4th Level	Total hydrocarbons	467	49.3	9.3 mg/m^3
Pipe Manifold	Total hydrocarbons	372	19.8	0.16 mg/m^3
Wire Line Deck 4th Level	Xylenes	467	49.3	(0.0040 ppm)
Pipe Manifold	Xylenes	372	19.8	<0.005 ppm

*N/A = not applicable

†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration

‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise

Activity/Location	Substance	Sampling Information* Time (min)	Sampling Information* Volume (Liters)	Sample Concentration†‡
Personal Breathing Zone Air Samples—Worker A				
Fire Technician, Main Deck	Benzene	592	59.3	<0.002 ppm
Fire Technician, Main Deck	2-Butoxyethanol	591	59.4	(0.0016 ppm)
Fire Technician, Main Deck	Dipropylene glycol butyl ether	591	59.4	<0.002 ppm
Fire Technician, Main Deck	Dipropylene glycol methyl ether	591	59.4	<0.001 ppm
Fire Technician, Main Deck	Ethyl benzene	592	59.3	<0.002 ppm
Fire Technician, Main Deck	Limonene	592	59.3	0.0044 ppm
Fire Technician, Main Deck	Naphthalene	592	59.3	<0.001 ppm
Fire Technician, Main Deck	Toluene	592	59.3	<0.002 ppm
Fire Technician, Main Deck	Total hydrocarbons	592	59.3	0.25 mg/m^3
Fire Technician, Main Deck	Xylenes	592	59.3	<0.003 ppm
Personal Breathing Zone Air Samples—Worker B				
Air Monitor Technician	Benzene	690	69.1	<0.002 ppm
Air Monitor Technician	2-Butoxyethanol	694	69.5	(0.0022 ppm)
Air Monitor Technician	Dipropylene glycol butyl ether	694	69.5	(0.0024 ppm)
Air Monitor Technician	Dipropylene glycol methyl ether	694	69.5	<0.001 ppm
Air Monitor Technician	Ethyl benzene	690	69.1	<0.001 ppm
Air Monitor Technician	Hydrogen sulfide	704	N/A	0 ppm
Air Monitor Technician	Limonene	690	69.1	0.0038 ppm
Air Monitor Technician	Naphthalene	690	69.1	<0.001 ppm
Air Monitor Technician	Toluene	690	69.1	(0.0026 ppm)
Air Monitor Technician	Total hydrocarbons	690	69.1	0.42 mg/m^3
Air Monitor Technician	Xylenes	690	69.1	(0.0030 ppm)
Personal Breathing Zone Air Samples—Worker C				
Well Test Field Tech, Production Deck	Benzene	765	76.3	<0.002 ppm
Well Test Field Tech, Production Deck	2-Butoxyethanol	759	75.7	(0.0015 ppm)
Well Test Field Tech, Production Deck	Dipropylene glycol butyl ether	759	75.7	(0.0017 ppm)
Well Test Field Tech, Production Deck	Dipropylene glycol methyl ether	759	75.7	<0.0009 ppm
Well Test Field Tech, Production Deck	Ethyl benzene	765	76.3	<0.001 ppm
Well Test Field Tech, Production Deck	Hydrogen sulfide	757	N/A	0 ppm
Well Test Field Tech, Production Deck	Limonene	765	76.3	0.0097 ppm

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker C (continued)				
Well Test Field Tech, Production Deck	Naphthalene	765	76.3	<0.001 ppm
Well Test Field Tech, Production Deck	Toluene	765	76.3	<0.001 ppm
Well Test Field Tech, Production Deck	Total hydrocarbons	765	76.3	0.30 mg/m^3
Well Test Field Tech, Production Deck	Xylenes	765	76.3	<0.001 ppm
Personal Breathing Zone Air Samples—Worker D				
Floor Hand, Rig Floor	Benzene	351	34.9	<0.002 ppm
Floor Hand, Rig Floor	2-Butoxyethanol	357	35.9	(0.0014 ppm)
Floor Hand, Rig Floor	Dipropylene glycol butyl ether	357	35.9	<0.002 ppm
Floor Hand, Rig Floor	Dipropylene glycol methyl ether	357	35.9	<0.0009 ppm
Floor Hand, Rig Floor	Ethyl benzene	351	34.9	<0.001 ppm
Floor Hand, Rig Floor	Hydrogen sulfide	351	N/A	0 ppm
Floor Hand, Rig Floor	Limonene	351	34.9	<0.001 ppm
Floor Hand, Rig Floor	Naphthalene	351	34.9	<0.001 ppm
Floor Hand, Rig Floor	Toluene	351	34.9	<0.002 ppm
Floor Hand, Rig Floor	Total hydrocarbons	351	34.9	0.12 mg/m^3
Floor Hand, Rig Floor	Xylenes	351	34.9	<0.003 ppm
Personal Breathing Zone Air Samples—Worker E				
Floor Hand, Rig Floor	Benzene	304	30.2	<0.002 ppm
Floor Hand, Rig Floor	2-Butoxyethanol	306	30.8	0.032 ppm
Floor Hand, Rig Floor	Dipropylene glycol butyl ether	306	30.8	<0.002 ppm
Floor Hand, Rig Floor	Dipropylene glycol methyl ether	306	30.8	<0.001 ppm
Floor Hand, Rig Floor	Ethyl benzene	304	30.2	<0.002 ppm
Floor Hand, Rig Floor	Hydrogen sulfide	304	N/A	0 ppm
Floor Hand, Rig Floor	Limonene	304	30.2	<0.001 ppm
Floor Hand, Rig Floor	Naphthalene	304	30.2	<0.001 ppm
Floor Hand, Rig Floor	Toluene	304	30.2	<0.002 ppm
Floor Hand, Rig Floor	Total hydrocarbons	304	30.2	0.08 mg/m^3
Floor Hand, Rig Floor	Xylenes	304	30.2	<0.003 ppm
Personal Breathing Zone Air Samples—Worker F				
Chief Mate, Cargo Deck	Acenaphthene	771	1550	<0.00006 mg/m^3
Chief Mate, Cargo Deck	Acenapthylene	771	1550	(0.000058 mg/m^3)
Chief Mate, Cargo Deck	Anthracene	771	1550	<0.00006 mg/m^3
Chief Mate, Cargo Deck	Benzo(a)anthracene	771	1550	<0.0001 mg/m^3
Chief Mate, Cargo Deck	Benzo(a)pyrene	771	1550	<0.0002 mg/m^3

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise (continued)

Activity/Location	Substance	Sampling Information* Time (min)	Sampling Information* Volume (Liters)	Sample Concentration†‡
Personal Breathing Zone Air Samples—Worker F (continued)				
Chief Mate, Cargo Deck	Benzo(b)fluoranthene	771	1550	<0.00006 mg/m^3
Chief Mate, Cargo Deck	Benzo(e)pyrene	771	1550	<0.0001 mg/m^3
Chief Mate, Cargo Deck	Benzo(g,h,i)perylene	771	1550	<0.0001 mg/m^3
Chief Mate, Cargo Deck	Benzo(k)fluoranthene	771	1550	<0.00007 mg/m^3
Chief Mate, Cargo Deck	Chrysene	771	1550	<0.00008 mg/m^3
Chief Mate, Cargo Deck	Dibenzo(a,h)anthracene	771	1550	<0.00007 mg/m^3
Chief Mate, Cargo Deck	Fluoranthracene	771	1550	<0.00008 mg/m^3
Chief Mate, Cargo Deck	Fluorene	771	1550	(0.00020 mg/m^3)
Chief Mate, Cargo Deck	Indeno(1,2,3-cd)pyrene	771	1550	<0.0001 mg/m^3
Chief Mate, Cargo Deck	Naphthalene	771	1550	0.00028 ppm
Chief Mate, Cargo Deck	Phenanthrene	771	1550	0.0059 mg/m^3
Chief Mate, Cargo Deck	Pyrene	771	1550	0.00084 mg/m^3
Chief Mate, Cargo Deck	Total PAHs	771	1550	0.012 mg/m^3
Personal Breathing Zone Air Samples—Worker G				
Fire Technician	Acenaphthene	723	1450	<0.00007 mg/m^3
Fire Technician	Acenapthylene	723	1450	(0.000083 mg/m^3)
Fire Technician	Anthracene	723	1450	<0.00007 mg/m^3
Fire Technician	Benzo(a)anthracene	723	1450	<0.0001 mg/m^3
Fire Technician	Benzo(a)pyrene	723	1450	<0.0002 mg/m^3
Fire Technician	Benzo(b)fluoranthene	723	1450	<0.00007 mg/m^3
Fire Technician	Benzo(e)pyrene	723	1450	<0.0001 mg/m^3
Fire Technician	Benzo(b)fluoranthene	723	1450	<0.00007 mg/m^3
Fire Technician	Benzo(e)pyrene	723	1450	<0.0001 mg/m^3
Fire Technician	Benzo(g,h,i)perylene	723	1450	<0.0001 mg/m^3
Fire Technician	Benzo(k)fluoranthene	723	1450	<0.00008 mg/m^3
Fire Technician	Chrysene	723	1450	<0.00009 mg/m^3
Fire Technician	Dibenzo(a,h)anthracene	723	1450	<0.00008 mg/m^3
Fire Technician	Fluoranthracene	723	1450	<0.00008 mg/m^3
Fire Technician	Fluorene	723	1450	0.00027 mg/m^3
Fire Technician	Indeno(1,2,3-cd)pyrene	723	1450	<0.0001 mg/m^3
Fire Technician	Naphthalene	723	1450	0.11 ppm
Fire Technician	Phenanthrene	723	1450	0.0025 mg/m^3
Fire Technician	Pyrene	723	1450	0.00050 mg/m^3
Fire Technician	Total PAHs	723	1450	0.0048 mg/m^3

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise (continued)				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Personal Breathing Zone Air Samples—Worker H				
Superintendant of ROV, Midship	Acenaphthene	713	1420	<0.00007 mg/m^3
Superintendant of ROV, Midship	Acenapthylene	713	1420	(0.000085 mg/m^3)
Superintendant of ROV, Midship	Anthracene	713	1420	<0.00007 mg/m^3
Superintendant of ROV, Midship	Benzo(a)anthracene	713	1420	<0.0001 mg/m^3
Superintendant of ROV, Midship	Benzo(a)pyrene	713	1420	<0.0002 mg/m^3
Superintendant of ROV, Midship	Benzo(b)fluoranthene	713	1420	<0.00007 mg/m^3
Superintendant of ROV, Midship	Benzo(e)pyrene	713	1420	<0.0001 mg/m^3
Superintendant of ROV, Midship	Benzo(g,h,i)perylene	713	1420	<0.0001 mg/m^3
Superintendant of ROV, Midship	Benzo(k)fluoranthene	713	1420	<0.00008 mg/m^3
Superintendant of ROV, Midship	Chrysene	713	1420	<0.00009 mg/m^3
Superintendant of ROV, Midship	Dibenzo(a,h)anthracene	713	1420	<0.00008 mg/m^3
Superintendant of ROV, Midship	Fluoranthracene	713	1420	0.000085 mg/m^3
Superintendant of ROV, Midship	Fluorene	713	1420	(0.00016 mg/m^3)
Superintendant of ROV, Midship	Indeno(1,2,3-cd)pyrene	713	1420	<0.0001 mg/m^3
Superintendant of ROV, Midship	Naphthalene	713	1420	0.00039 ppm
Superintendant of ROV, Midship	Phenanthrene	713	1420	0.0055 mg/m^3
Superintendant of ROV, Midship	Pyrene	713	1420	0.00092 mg/m^3
Superintendant of ROV, Midship	Total PAHs	713	1420	0.014 mg/m^3
Personal Breathing Zone Air Samples—Worker I				
Electrician	Acenaphthene	698	1410	<0.00007 mg/m^3
Electrician	Acenapthylene	698	1410	<0.00006 mg/m^3
Electrician	Anthracene	698	1410	<0.00007 mg/m^3
Electrician	Benzo(a)anthracene	698	1410	<0.0001 mg/m^3

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise (continued)				
Activity/Location	**Substance**	**Sampling Information***		**Sample Concentration†‡**
		Time (min)	**Volume (Liters)**	
Personal Breathing Zone Air Samples—Worker I (continued)				
Electrician	Benzo(a)pyrene	698	1410	<0.0002 mg/m^3
Electrician	Benzo(b)fluoranthene	698	1410	<0.00007 mg/m^3
Electrician	Benzo(e)pyrene	698	1410	<0.0001 mg/m^3
Electrician	Benzo(g,h,i)perylene	698	1410	<0.0001 mg/m^3
Electrician	Benzo(k)fluoranthene	698	1410	<0.00008 mg/m^3
Electrician	Carbon Monoxide	696	N/A	Range: 0–5 ppm; Avg: 0 ppm
Electrician	Chrysene	698	1410	(0.00041 mg/m^3)
Electrician	Dibenzo(a,h)anthracene	698	1410	<0.00008 mg/m^3
Electrician	Fluoranthracene	698	1410	<0.00009 mg/m^3
Electrician	Fluorene	698	1410	(0.00018 mg/m^3)
Electrician	Indeno(1,2,3-cd)pyrene	698	1410	<0.0001 mg/m^3
Electrician	Naphthalene	698	1410	0.00026 ppm
Electrician	Phenanthrene	698	1410	0.0071 mg/m^3
Electrician	Pyrene	698	1410	0.0016 mg/m^3
Electrician	Total PAHs	698	1410	0.014 mg/m^3
Personal Breathing Zone Air Samples—Worker J				
Motorman, Lower Machine Deck	Acenaphthene	574	1160	<0.00009 mg/m^3
Motorman, Lower Machine Deck	Acenapthylene	574	1160	<0.00008 mg/m^3
Motorman, Lower Machine Deck	Anthracene	574	1160	<0.00009 mg/m^3
Motorman, Lower Machine Deck	Benzo(a)anthracene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Benzo(a)pyrene	574	1160	<0.0003 mg/m^3
Motorman, Lower Machine Deck	Benzo(b)fluoranthene	574	1160	<0.00009 mg/m^3
Motorman, Lower Machine Deck	Benzo(e)pyrene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Benzo(g,h,i)perylene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Benzo(k)fluoranthene	574	1160	<0.00009 mg/m^3
Motorman, Lower Machine Deck	Chrysene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Dibenzo(a,h)anthracene	574	1160	<0.00009 mg/m^3
Motorman, Lower Machine Deck	Fluoranthracene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Fluorene	574	1160	(0.00019 mg/m^3)

Table 4. Personal breathing zone and area air concentrations for substances measured on June 23, 2010 on the Discoverer Enterprise (continued)

Activity/Location	Substance	Sampling Information*		Sample Concentration†‡
		Time (min)	Volume (Liters)	
Personal Breathing Zone Air Samples—Worker J (continued)				
Motorman, Lower Machine Deck	Hydrogen sulfide	654	N/A	0 ppm
Motorman, Lower Machine Deck	Indeno(1,2,3-cd)pyrene	574	1160	<0.0001 mg/m^3
Motorman, Lower Machine Deck	Naphthalene	574	1160	0.00026 ppm
Motorman, Lower Machine Deck	Phenanthrene	574	1160	0.012 mg/m^3
Motorman, Lower Machine Deck	Pyrene	574	1160	0.0041 mg/m^3
Motorman, Lower Machine Deck	Total PAHs	574	1160	0.020 mg/m^3
Area Air Samples				
Well Test Deck	Benzene	751	75.6	<0.0008 ppm
Moon Pool	Benzene	224	22.5	<0.003 ppm
Well Test Deck	2-Butoxyethanol	751	74.9	0.0026 ppm
Moon Pool	2-Butoxyethanol	224	22.5	(0.0021 ppm)
Well Test Deck	Carbon Monoxide	744	N/A	Range: 0–5 ppm; Avg: 0 ppm
Well Test Deck	Dipropylene glycol butyl ether	751	74.9	<0.0009 ppm
Moon Pool	Dipropylene glycol butyl ether	224	22.5	<0.003 ppm
Well Test Deck	Dipropylene glycol methyl ether	751	74.9	<0.0004 ppm
Moon Pool	Dipropylene glycol methyl ether	224	22.5	<0.001 ppm
Well Test Deck	Ethyl benzene	751	75.6	<0.0006 ppm
Moon Pool	Ethyl benzene	224	22.5	<0.002 ppm
Well Test Deck	Limonene	751	75.6	(0.0011 ppm)
Moon Pool	Limonene	224	22.5	<0.002 ppm
Well Test Deck	Naphthalene	751	75.6	<0.0005 ppm
Moon Pool	Naphthalene	224	22.5	<0.002 ppm
Well Test Deck	Toluene	751	75.6	<0.0007 ppm
Moon Pool	Toluene	224	22.5	<0.002 ppm
Well Test Deck	Total hydrocarbons	751	75.6	0.13 mg/m^3
Moon Pool	Total hydrocarbons	224	22.5	0.080 mg/m^3
Well Test Deck	Xylenes	751	75.6	<0.001 ppm
Moon Pool	Xylenes	224	22.5	<0.004 ppm

*N/A = not applicable
†Concentrations reported as "<" were not detected; the given value is the minimum detectable concentration
‡Concentrations in parentheses were between the minimum detectable concentration and the minimum quantifiable concentration (parentheses are used to point out there is more uncertainty associated with these values than values above the minimum quantifiable concentration)

Table 5. Health symptom survey—demographics by vessel			
	Development Driller II*	**Discoverer Enterprise†**	**Unexposed‡**
Number of participants	28	34	103
Age range	22–60	21–55	18–70
Race			
White	71%	82%	40%
Hispanic	4%	0%	29%
Asian	0%	0%	9%
Black	21%	12%	19%
Other/Missing	4%	6%	3%
Male	96%	97%	96%
Days worked oil spill	13–70	7–65	0–45
Days worked boat	0–60	6–50	0

* Surveys were collected aboard the Development Driller II on June 21–22, 2010.

†Surveys were collected aboard the Discoverer Enterprise on June 22–23, 2010.

‡Participants were recruited from the Venice Field Operations Branch and the Venice Commanders' Camp. Those who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals were included in this group.

Table 6. Health symptom survey—reported injuries and symptoms by vessel			
	Development Driller II*	**Discoverer Enterprise †**	**Unexposed‡**
Number of participants	28	34‡	103
Injuries			
Scrapes or cuts	1	1	11 (11%)
Burns by fire	0	0	1 (1%)
Chemical burns	0	0	0
Bad Sunburn	0	0	8 (8%)
Constitutional symptoms			
Headaches	7	12	5 (5%)
Feeling faint, dizziness, fatigue or exhaustion, or weakness	4	2	13 (13%)
Eye and upper respiratory symptoms			
Itchy eyes	5	5	5 (5%)
Nose irritation, sinus problems, or sore throat	5	7	16 (16%)
Metallic taste	0	0	0
Lower respiratory symptoms			
Coughing	4	1	8 (8%)
Trouble breathing, short of breath, chest tightness, wheezing	3	1	4 (4%)
Cardiovascular symptoms			
Fast heart beat	0	0	1 (1%)
Chest pressure	1	0	0
Gastrointestinal symptoms			
Nausea or vomiting	2	3	3 (3%)
Stomach cramps or diarrhea	5	0	7 (7%)
Skin symptoms			
Itchy skin, red skin, or rash	6	1	8 (8%)
Musculoskeletal symptoms			
Hand, shoulder, or back pain	3	0	6 (6%)
Psychosocial symptoms			
Feeling worried or stressed	9	2	4 (4%)
Feeling pressured	4	1	2 (2%)
Feeling depressed or hopeless	0	0	1 (1%)
Feeling short tempered	2	0	4 (4%)
Frequent changes in mood	3	0	3 (3%)
Heat stress symptoms§			
Any	8	13	21 (20%)
4 or more symptoms	2	1	3 (3%)

*Surveys were collected aboard the Development Driller II on June 21–22, 2010.
†Surveys were collected aboard the Discoverer Enterprise on June 22–23, 2010.
‡Participants were recruited from the Venice Field Operations Branch and the Venice Commanders' Camp. Those who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals were included in this group.
§Headache, dizziness, feeling faint, fatigue or exhaustion, weakness, fast heartbeat, nausea, red skin, or hot and dry skin.

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EXHIBIT
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Health Hazard Evaluation of Deepwater Horizon Response Workers

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The front cover shows a controlled oil burn (in-situ burn) on the Gulf of Mexico during the Deepwater Horizon Response: June 2010.

Contents

Introduction

The April 20, 2010, explosion and collapse of the BP Deepwater Horizon oil platform in the Gulf of Mexico resulted in the release of millions of barrels of oil into Gulf waters. The response to this disaster involved the efforts of tens of thousands of workers in a variety of capacities across Louisiana, Mississippi, Alabama, Florida, Texas, and in the Gulf of Mexico itself. The diverse work included oil and tar ball removal from beaches, oil skimming and booming near shores, burning of surface oil near the source of the oil release, surface application of dispersant by vessels and aircraft, and containment and recovery work on vessels at the release site. The nature of these activities raised concerns about potential occupational exposures to chemical and physical hazards and mental stressors. The Deepwater Horizon oil release was an unprecedented event in the United States in many respects, requiring response work across a vast area of multiple jurisdictions. The type, location, and quantities of oil released; the types and quantities of dispersant used; and climatic and geographical conditions differentiate this release from past oil spills.

On May 28, 2010, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from BP management concerning health effects experienced by responders to the oil release. The request was prompted by the May 26, 2010, hospitalization of seven fishermen who were working in BP's Vessels of Opportunity (VoO) program in the Gulf of Mexico. The fishermen had been hospitalized for symptoms that were initially believed to be related to exposures experienced during their response activities, particularly booming and skimming oil.

In response to this request, we began an investigation on June 2, 2010, with an opening meeting held at the BP Operations Center in Houma, Louisiana. In attendance were representatives from NIOSH, BP, the Center for Toxicology and Environmental Health (CTEH), O'Brien's Response Management, the U.S. Coast Guard (USCG), and the Occupational Safety and Health Administration (OSHA). Objectives of this opening meeting were to discuss the initial investigations conducted by CTEH and OSHA into the events surrounding the hospitalization of the fishermen and to plan the NIOSH investigation. These plans included interviews, health symptom surveys, and on-site industrial hygiene assessments of response work activities similar to those performed by the fishermen.

As the plans were developing, BP requested that we expand the scope of the HHE to include all major offshore response activities. In addition to oil booming and skimming conducted by workers on VoO vessels, these activities included aerial and vessel-based dispersant releases, in-situ surface oil burning, containment and recovery work at the oil source, and other related offshore oil removal activities. In the weeks that followed, teams of NIOSH industrial hygienists, medical officers, and other occupational health specialists conducted on-site investigations at locations throughout the Gulf region to collect quantitative and qualitative data on potential worker exposures, health symptoms, work practices and procedures, and work organization.

On June 22, 2010, NIOSH received a request from BP for a second HHE to investigate potential hazards associated with onshore response work activities. In response to this request, teams of NIOSH personnel evaluated practices and procedures including wildlife cleanup operations, beach cleanup operations, and decontamination and waste management activities throughout the states of Louisiana, Alabama, Mississippi, and Florida. In contrast to the offshore evaluations, which relied on traditional industrial hygiene exposure assessment methodologies and quantitative exposure monitoring to identify potential hazards, the onshore assessment relied on qualitative assessment techniques, including the use of professional judgment and expertise during observations of onshore work activities. Health symptom surveys, however, were similar to those used for the offshore evaluations.

The goals of the NIOSH HHE assessments were to describe acute health effects, evaluate occupational exposures in qualitative or quantitative assessments, and generate hypotheses regarding symptoms potentially related to work activities. These assessments were not intended to describe or investigate potential long-term or chronic health effects. The results of these investigations were reported in a series of nine interim reports and report summaries posted on the NIOSH website. The full reports were distributed electronically to key contacts for each work activity evaluated. Included in the reports were conclusions regarding the extent of hazards and exposures identified as well as recommendations for improving workplace conditions. Furthermore, all exposure and health symptom survey data were compiled in electronic spreadsheets and posted on the NIOSH website. This information can be accessed at http://www.cdc.gov/niosh/topics/oilspillresponse/gulfspillhhe.html. Additional information about other components of the NIOSH Deepwater Horizon response activities outside of the HHE investigation, including response worker rostering efforts, analyses of injury and illness data, and guidance and educational materials developed for the response can be found on the NIOSH website at http://www.cdc.gov/niosh/topics/oilspillresponse/.

This final report summarizes our evaluations made during the course of the offshore and onshore HHE investigations and describes the conditions and characteristics encountered during the event. Overarching conclusions and recommendations drawing from the entirety of the HHE investigations are also presented.

Overview and Results

Review and Evaluation of Hospitalizations

In response to the BP request to evaluate the May 26, 2010, hospitalizations of seven fishermen involved in VoO operations, we reviewed hospital records from West Jefferson Medical Center in Marrero, Louisiana, BP Healthcare Provider Reporting Forms completed by nurse case managers, and the OSHA preliminary Incident Report of Fishermen Evacuated near Grand Isle Shipyard. We also interviewed nurse case managers and CTEH and OSHA investigators. Although all seven fishermen were hospitalized on the same day, we found that their symptoms could not be linked to the chemical dispersant that some of the fishermen had originally suspected. The seven fishermen worked on five different vessels, none of which were operating in the area of dispersant use at the time. Most of the seven fishermen reported headache, upper respiratory irritation or congestion, and nausea. Although these symptoms had disappeared or decreased in severity by the time the fishermen arrived at the hospital, they were admitted for observation as a precaution because they had reported chemical exposure. Two fishermen were hospitalized for potentially serious medical problems that were unrelated to oil or chemical exposure. All seven patients were discharged when their condition was determined to be stable or when test results were negative. Six were discharged within 1 day of admission, and the seventh was discharged after an additional day of testing. We concluded that the symptoms of headache, upper respiratory irritation or congestion, and nausea were unlikely to be related to dispersant exposure. Work-related factors (e.g., heat, fatigue, and unpleasant odors from undiluted terpene solutions used for cleaning boat decks and equipment) might have contributed to workers' symptoms.

In the period after these seven hospitalizations, the Louisiana Department of Health and Hospitals received reports of 10 additional hospitalized response workers. We reviewed these workers' hospital records. The conditions of these 10 hospitalized response workers were more severe than the conditions of the seven fishermen hospitalized on May 26, 2010, with hospitalization times ranging from 1 to 6 nights.

Five of the 10 workers, including onshore and offshore workers, identified heat as a major problem. The five workers who reported heat exposure also reported a variety of work-related and personal risk factors for heat illness; several reported multiple risk factors. All five of these workers had evidence of dehydration or a diagnosis of heat exhaustion or possible heat stroke. Five of the 10 workers (one of whom had also reported heat exposure) reported exposures to oil, hydrocarbons, or dispersant. The medical records of these five did not include information to identify specific chemicals, indicate how they came into contact with those chemicals, or describe how long they were exposed. It was reported that two of these workers were instructed to avoid exposures and, if exposed, to wear a respirator. However, the medical records of these two workers did not include sufficient detail about their oil and chemical exposures to determine whether their symptoms or diagnoses could have been related to chemical exposure and whether respiratory protection was necessary.

Exposure Evaluations of Offshore Work

Oil Dispersant Release Activities

We conducted two evaluations on board vessels releasing dispersant. These vessels were deployed to perform small-scale releases of dispersant in an area with surface oil contamination.

On June 4–5, 2010, we evaluated potential exposures experienced by workers on two vessels, the International Peace and the Warrior. During this evaluation, we conducted personal breathing zone (PBZ) and area air monitoring on both vessels (which maintained positions close to each other) during and after the application of 50 gallons of Corexit® EC9500A dispersant (Nalco, Naperville, Illinois) from the International Peace onto surface oil. An additional aerial release of 125 gallons of this dispersant onto the surface oil occurred from a support aircraft in the area. Sampling was conducted for volatile organic compounds (VOCs), propylene glycol (a component of the dispersant), diesel exhaust, mercury (a possible component of crude oil), the benzene soluble fraction of total particulate matter, carbon monoxide (CO), and hydrogen sulfide (H_2S). The measured substances were either not detected or were present at low concentrations below individual occupational exposure limits (OELs).

On June 21–22, 2010, we conducted further exposure assessments on board the International Peace. During this evaluation, we conducted air monitoring for a number of the substances listed above during and after the application of 50 gallons of Corexit® EC9500A dispersant onto surface oil from the vessel. The substances measured were either not detected or were at concentrations well below OELs.

In-Situ Oil Burning

We assessed exposures during in-situ (i.e., on site) burns of surface oil on June 8–10, 2010. The in-situ burn team was composed of a fleet of vessels including two lead vessels (the Premier Explorer and the Sea Fox), support and safety vessels, shrimping trawlers, and rigid-hulled inflatable boats. Each shrimping trawler and a partner trawler towed one end of an approximately 300-foot long boom behind them, creating a U-shaped area to contain a quantity of surface oil suitable for burning. The duration of the burn depended on the quantity of oil enclosed by the boom and ranged from 45 minutes to 6½ hours. Typically, one to five burns could be conducted by each trawler pair per day. During a burn, the trawlers were located approximately 300 feet from the area within the boom where the burn was occurring.

During the evaluation, we conducted PBZ and area air sampling on shrimping trawlers towing booms during in-situ burns and on boats from which the burns were ignited. Sampling was conducted for VOCs, aldehydes, CO, H_2S, benzene soluble fraction of total particulate matter, diesel exhaust, and mercury. Exposures for all compounds sampled were either below detectable concentrations or well below applicable OELs, with one exception being a peak exposure of 220 parts per million (ppm) of CO recorded on the double-engine ignition boat. This peak was likely due to the build-up of exhaust from the gasoline powered engines when idling with no movement of the boat and little wind.

Oil Booming, Skimming, and Vacuuming

During June 10–20, 2010, we assessed exposures on six fishing and shrimping trawlers in the VoO program that were assigned to remove surface oil by booming and skimming. While coordinating and preparing for the evaluations on board the VoOs, we were informed that the presence of oil in any specific location was sporadic because the Gulf currents moved the oil patches frequently. On days when oil was not present on the water surface in the areas to which these vessels were assigned, the captains often directed their vessels through patches of foam (described by the crew as “dispersant foam”) on the sea surface to break up this foam.

We conducted PBZ and area air sampling for VOCs, propylene glycol, diesel exhaust, mercury, CO, H_2S, total particulate matter, and the benzene soluble fraction of total particulate matter during work activities on the six vessels. During these evaluations, the VoOs on which we were present spent most of their time scouting for oil and breaking up foam patches. Because no oil was encountered by the VoOs on these days, we did not observe any oil cleanup work. The PBZ and area air concentrations of the measured compounds were below detectable levels or well below OELs.

An exposure assessment of an offshore oil skimming and recovery mission involving a platform supply vessel, the Queen Bee, was conducted on June 14–16, 2010. The Queen Bee was retrofitted with a USCG-operated weir skimmer, skimming control stand, high volume pumping unit, boom system, three on-deck 500-barrel storage capacity tanks, and an industrial crane used to move booms and the skimmer. The vortex weir skimmer consisted of a heavy-duty frame holding a central collection bowl and three floats. The central bowl of the skimmer created a void in the water into which the oil/water mix poured. Under the bowl were the hydraulic lines and the hose for transporting the oil/water mix to the on-deck storage tanks.

We used PBZ and area air sampling to evaluate exposures to VOCs, propylene glycol, diesel exhaust, CO, H_2S, total particulate matter, and the benzene soluble fraction of total particulate matter. PBZ and area air concentrations of the contaminants measured were below applicable OELs. The potential existed for dermal contact with oil while placing and removing the skimmer and boom from the water and during cleaning activities on deck. However, workers wore the necessary protective equipment during tasks with increased potential for dermal contact.

On June 25, 2010, we visually inspected oil skimming operations on a set of barges located in Coup Abel Pass, offshore from Grand Isle, Louisiana. The 18 barges were divided into six sets of three barges each, with each set containing a semi-truck fitted with a vacuuming system. To vacuum oil and potentially oil-contaminated plant material from the water surface near the side of the barges, workers extended a 2-inch diameter rubber vacuum hose over the side of the barge deck and lowered it approximately 8 feet to the water surface. We noted a lack of fall protection for the workers, a lack of hearing protection during vacuuming and pile driving, and musculoskeletal risks from working in awkward postures with sustained or repeated back flexion and twisting.

Oil Source Activities

On June 21–23, 2010, we assessed exposures aboard the Development Driller II (DDII) and the Discoverer Enterprise, located at the site of the Deepwater Horizon Mississippi Canyon 252 Well Number 1. At the time of the NIOSH evaluation, DD II was drilling a relief well for the purpose of pumping mud and concrete into the blown well to suppress the release of crude oil. The Discoverer Enterprise, which was located directly above the blown well, captured oil and gas from the damaged well through a lower marine riser package cap, which was placed on top of the failed Deepwater Horizon blowout preventer.

We conducted PBZ and area air sampling aboard the DD II on June 21, 2010, and aboard the Discoverer Enterprise on June 23, 2010. Air sampling on these vessels was conducted to characterize exposures of workers who were closest to the point of release where the potential for exposure to VOCs from the oil was expected to be greatest. Unlike crews and cleanup workers aboard VoOs and cleanup workers onshore, the crews of the DD II and Discoverer Enterprise were performing operations that utilized their usual and standard work skills, PPE, training, and experience (i.e., well drilling aboard the DD II and storage and processing of crude oil aboard the Discoverer Enterprise). We surmised that the only source of nonroutine occupational exposures aboard these vessels to which the crews might have been exposed was oil on the sea surface that had been released from the blown well. PBZ and area air sampling was conducted for VOCs, sulfur compounds, propylene glycol ethers, polycyclic aromatic hydrocarbons (PAHs), CO, and H_2S. Airborne concentrations for all contaminants evaluated on the DD II and the Discoverer Enterprise were well below applicable OELs.

Exposure Evaluations of Onshore Work

Wildlife Cleanup

In June and July 2010, we made multiple site visits to assess factors related to potential exposures and occupational hazards at onshore wildlife cleaning and rehabilitation centers. The wildlife cleaning centers visited included two in Louisiana (Fort Jackson and Grand Isle) and one each in Alabama (Theodore), Florida (Pensacola), and Mississippi (Gulfport).

Birds were the most common type of wildlife being cleaned and rehabilitated at the centers. Common activities involved in the cleaning and rehabilitation process for most birds included search and retrieval; baseline health assessment of the birds; stabilization, including rehydration and feeding if needed; a series of cleaning steps that usually included the use of compounds derived from vegetable oils as pretreatment, followed by cleaning with repeated detergent and water rinses; and post-cleaning placement in a drying area, followed by placement in holding pens for rehabilitation while awaiting transport.

The task of wildlife cleaning and rehabilitation presented the opportunity for repeated and prolonged skin contact with water used in washing and rinsing the animals. This water varied from "oily" to "clean" as the animals went through the cleaning process. Routine use of PPE included safety glasses, gloves, sleeve protectors, rubber boots, Tyvek® suits, other protective coveralls, and plastic aprons. Workers handling the wildlife prior to cleaning had some potential for direct skin exposure to the oil on the animals; with PPE use, this exposure was observed to be minimal in most cases.

We identified heat as a primary exposure of concern. All sites were aware of concerns about heat and were taking actions to prevent heat stress in workers. Sites established either a formal work-rest schedule or managed potential heat stress in workers by requiring frequent rest breaks, encouraging fluid replacement, and observing workers for signs of heat-related illness.

Beach Cleanup

In July 2010, we made multiple visits to onshore worksites where beach cleanup was occurring. Onshore worksites were chosen for evaluation based on input from the command centers. Among the factors considered in selection of sites were estimates of the level of contamination likely to be encountered, type of work activity, and number of workers. Efforts were made to evaluate worksites in each of the four affected states of Louisiana, Mississippi, Alabama, and Florida.

Sixty-seven onshore worksites were evaluated. At 59 of the 67 sites, a structured exposure assessment checklist was used. Of those 59 sites, 36 (61%) were beach cleaning sites, with six in Alabama, seven in Florida, five in Louisiana, and 18 in Mississippi. The exposure assessment checklist included a qualitative assessment by the NIOSH investigator about the level of oil residue at the site at the time of the survey. We judged 24 sites to have a level of light residue, six to have a level of moderate residue, and three to have a level of heavy residue. All sites with heavy residue and five of the six with moderate residue were in Mississippi. Even at worksites where oil residue was judged to be heavy, worker exposure to oil residue typically was judged to be limited because of the nature of the oil residue (oil-soaked sand or solid to semisolid tar balls) and the use of PPE. We saw no evidence of exposure to dispersant at the shore cleaning sites.

During the evaluations, we observed that beach cleaning tasks involved risk factors for musculoskeletal disorders, including repetitive awkward postures of the back and upper extremities while using moderate force. Workers at the beach cleaning sites used shovels, rakes, and improvised hand tools to manually remove tar balls from the sand. The most common operation observed involved workers walking the beach using tools to collect solid or semi-solid oil residue and placing the residue in large trash bags. Generally, the workers placed two or three shovels of material into a bag; filled bags weighed about 10 to 20 pounds. The main risk factors observed in the use of these tools included the following: repetitive and sustained back flexion/twisting, squatting, ground-sitting, or kneeling; repetitive upper extremity motions; awkward wrist/forearm twisting; moderate upper extremity forces to handle tools and mixtures of sand and tar balls; and moderate low back force to handle bags of sand and tar balls. We recommended further evaluation and testing of different types of manual tools to improve their design, manufacture, and selection for future onshore oil spill cleaning work.

We identified heat to be a primary exposure of concern. Site supervisory staff measured heat and humidity in a variety of ways at the work sites. Recommended work/rest regimens were based on the heat index. The guidelines called for work/rest regimens varying from “no limit” to the most limiting regimen of 10 minutes of work followed by 50 minutes of rest. We observed variability in application of the heat stress guidelines. Some contractors appeared to do the minimum to follow the guidelines, while others followed a work/rest regimen more conservative than called for by the guidelines.

Decontamination and Waste Management

During July and August, we conducted observational exposure assessments and site characterizations at 15 equipment and boat repair/decontamination or waste management sites throughout Florida, Mississippi, Alabama, and Louisiana. Decontamination activities provided potential for exposure to weathered oil and cleaning agents. The use of diesel- and gasoline-powered equipment also posed risks of potential exposures to diesel exhaust, CO, and noise. However, we deemed heat stress as the most significant hazard at the visited sites; we noted that decontamination workers were at increased risk because of layering of PPE. We found that issues related to heat appeared well-managed and controlled by on-site safety contractors. For boom repair workers, skin exposures to solvent-based chemical adhesives were identified as a potential health hazard because workers had not been provided or were not wearing chemically-resistant gloves at the times of the assessments. The ergonomic hazards faced by repair/decontamination and waste management workers were unique among response workers. Work tasks such as handling and moving booms and other equipment to be cleaned and the actions associated with operating the pressure washers led to awkward and heavy lifting tasks, which could contribute to musculoskeletal symptoms.

In August, we conducted quantitative exposure assessments at two boom and vessel decontamination operations in Port Fourchon, Louisiana. Decontamination job tasks included spraying a chemical cleaner onto oil-contaminated equipment with a standard hand-held garden-type sprayer, scrubbing the equipment with brushes, and rinsing the oil-contaminated equipment with water supplied by diesel-operated pressure washers. PPE used by these workers included protective steel-toed boots, an inner nitrile glove under an outer chemical resistant glove, full-body coveralls, hard hat, safety glasses, and face shield. To minimize heat stress, work/rest regimens consisting of cycles of 20 minutes of work followed by 40 minutes of rest in a cooled or shaded environment were enforced during each work shift.

We collected PBZ and area air samples for VOCs, glycol ethers, total particulate matter, the benzene-soluble fraction of the total particulate matter, PAHs, CO, diesel exhaust, and noise during decontamination activities. Temperature and relative humidity measurements were also taken. Examples of VOCs found to be present included C_9-C_{16} aliphatic hydrocarbons, 2-butoxyethanol, propylene glycol t-butyl ether, and limonene. The air concentrations for these and other chemicals quantified were below applicable OELs. Noise exposure monitoring showed the potential for noise exposures above the NIOSH recommended exposure limit of 85 decibels A-weighted. Recommendations were made for employees to wear hearing protection during pressure washing, to use such hearing protection within the context of a hearing conservation program, and for site safety officers to monitor these and other work practices for potential noise exposure hazards. We observed heat stress as a significant issue for workers, particularly due to the PPE required for these activities. Recommendations were made for continued application of the enforced work/rest regimen and attention to worker training in the recognition of the heat stress hazard, potential symptoms associated with heat stress, and the importance of hydration.

Infirmary Log Reviews

We collected and reviewed daily infirmary logs from June 1–30, 2010, for response workers seen at the Deepwater Horizon Venice, Louisiana, Branch Infirmary. Among the 1004 reported visits, 363 (36%) were for ear, nose, and throat and respiratory complaints. Of the respiratory complaint visits, 230 (63%) were classified as sinus/congestion. Orthopedic/injury was the second most commonly reported complaint, accounting for 146 (15%) visits. Heat-related disorders were reported in 2% of visits; however, nonspecific signs (e.g., headache, dizziness, and cramps) recorded separately could have been early signs of heat-related disorders. Of these 1004 infirmary visits, 717 (71%) resulted in on-site evaluation by emergency medical technicians and treatment with over-the-counter medications. Although this evaluation analyzed infirmary log data from only one location for 1 month of the response, we determined that these data do not reveal unrecognized or unreported occupational illness due to workplace exposures.

Health Symptom Surveys

Voluntary health symptom surveys were distributed to workers at offshore and onshore locations where we conducted evaluations. Given the magnitude of the response and large number of response workers employed in the cleanup, we administered the survey to convenience samples of workers performing a wide variety of job tasks. Throughout our health symptom survey analysis, we compared groups of workers self-reporting exposure(s) to a comparison group of workers recruited at the Venice Field Operations Branch and the Venice Commanders' Camp who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals. Although we believe our recommendations, which are based on the results of these surveys, are applicable for response workers performing similar tasks in other locations, we acknowledge that we surveyed a small subset of the entire response workforce.

From June 7–22, 2010, 826 surveys were completed by workers in the Plaquemines Branch Incident Command System, also known as the Venice, Louisiana, Field Operations Branch (FOB). Workers were asked to report symptoms they experienced while working during response activities. The most frequently reported symptoms were headache, upper respiratory symptoms, and symptoms consistent with heat stress. Workers who reported exposures to oil and dispersant reported higher prevalences of all types of symptoms compared to workers who reported no such exposures.

During the June 4–5, 2010, evaluation of dispersant release on board the International Peace and the Warrior, health symptom surveys were distributed to vessel workers immediately and 4 hours after release of the dispersant. Of the 17 respondents, very few on either vessel reported upper or lower respiratory, gastrointestinal, musculoskeletal, or psychological symptoms or injuries. Those on the International Peace reported very few symptoms, while some workers on the Warrior reported constitutional (i.e., headaches and fatigue) and skin symptoms, similar to a comparison group of workers recruited from the Venice, Louisiana FOB and the Commanders' Camp who reported that they had not worked on boats and had no exposures to oil, dispersant, cleaner, or other chemicals. Health symptom surveys were also distributed to five vessel workers on board the International Peace during the June 21–22, 2010 evaluation. Health symptoms reported by vessel workers surveyed during this evaluation included itching eyes, exhaustion, musculoskeletal pain, and feelings of "work pressure."

We distributed and collected health symptom survey forms on June 10, 2010, for workers on board the lead in-situ burn team vessels, the Sea Fox and the Premier Explorer. The types of symptoms reported by the 39 respondents were similar to those reported by response workers who were not performing in-situ burning. The most frequently reported symptoms on both vessels were similar: upper respiratory symptoms and constitutional symptoms. Workers on the Sea Fox also reported itchy eyes, coughing, musculoskeletal pain, and psychosocial symptoms (i.e., feeling worried, stressed, pressured, etc.).

Overall, workers involved in the in-situ burn did report a higher frequency of these symptoms than the comparison group.

Health symptom surveys were distributed at a USCG safety and administrative meeting on June 18, 2010, to workers who were either USCG personnel providing safety oversight to off-shore vessels or administrative/command services at the Venice, Louisiana FOB, or civilian contractors providing safety oversight for other responders working off-shore. A total of 74 attendees completed the survey. The types of symptoms reported among these USCG members and contractor safety personnel were similar to a comparison group of response workers who reported no exposures to oil, dispersant, cleaner, or other chemicals. Headaches, however, were reported more frequently in those surveyed at the USCG safety meeting. Those reporting exposure to oil and dispersants had significantly higher prevalences of upper respiratory symptoms and cough than those not exposed. Symptoms related to heat exposure were the most frequent in all groups.

We collected self-administered health symptom surveys from response workers on a floating barge hotel, Floating City #1 (located 10 miles northeast of Venice, Louisiana, at the mouth of the Baptiste Collette channel), on June 19–23, 2010. Of 500 eligible responders, captains, and deckhands, 189 completed the survey. The types of symptoms reported among respondents were similar to those reported by a comparison group of response workers who reported no exposures to oil, dispersant, cleaner, or other chemicals. Symptoms related to heat exposure and upper respiratory symptoms were the most frequently reported in both groups.

Health symptom surveys were distributed on June 21–23, 2010, to a convenience sample of workers onboard the DDII and Discoverer Enterprise at the site of the oil release. Overall, the 28 workers onboard the DDII who completed the survey reported a wider variety and a higher number of health symptoms than the 34 employees aboard the Discoverer Enterprise or the comparison group. Headache and symptoms consistent with heat stress were reported among survey respondents on both vessels, while symptoms of feeling worried or stressed, and feeling pressured were highest among respondents who worked aboard the DDII.

During June and July 2010, we asked workers at onshore wildlife cleanup sites to complete a health symptom survey. Most of the health outcomes and symptoms reported in these surveys were more prevalent in the wildlife cleaning workers than the comparison group of workers who had no reports of exposure to oil, dispersant, or other chemicals. Among the 54 wildlife cleaning workers who completed the survey, scrapes and cuts were reported by 67%, itchy or red skin or rash were reported by 46%, and symptoms of headache or feeling faint, dizzy, or fatigued were reported by 35%. Hand, shoulder, or back pain was reported by 39% of the wildlife cleaning workers. Twenty-four percent of participants reported one or more of five psychosocial symptoms (feeling worried or stressed; feeling pressured; feeling depressed or hopeless; feeling short-tempered; frequent changes in mood).

In July 2010, health symptom surveys were distributed to beach cleanup workers. More injuries and symptoms were reported among the 1,899 responding workers than among the comparison group. One or more of nine nonspecific symptoms that could be related to heat stress was reported by 37% of the beach cleaning workers. Four or more of those symptoms, a constellation of symptoms considered in this evaluation as a more specific indicator of heat stress, were reported by 7%. Among the individual symptoms reported most frequently were headaches (28%); coughing (19%); and hand, shoulder, or back pain (17%). Eighteen percent of participants reported one or more of five psychosocial symptoms.

We distributed health symptom surveys to workers at repair/decontamination and waste management sites during July and August 2010. One or more of nine nonspecific symptoms that could be related to heat stress were reported by 38% of the 499 responding repair/decontamination and waste management workers. Four or more of the symptoms which were more specific indicators of heat stress were reported by 6%. Other individual symptoms reported most frequently were headaches, coughing, and hand, shoulder, or back pain, as well as one or more of five psychosocial symptoms.

Psychosocial and Work Organization Issues

In August 2010, we conducted focus groups to assess work organization processes and practices as well as job stress among safety professionals involved in the response. Work organization refers to the work processes (the way jobs are designed and performed) and to the organizational practices (management and work methods and accompanying workforce policies) that influence how jobs are designed. The purpose of these focus groups was to gain a more in-depth understanding of the way the work was designed and performed, the policies that were in place, and job stress and protective (e.g., coping) factors among emergency response workers during response operations. Safety professionals operating out of Venice, Louisiana, were chosen as the target population because of their knowledge of the organization of work, policies, and procedures for response workers on the water. While not necessarily representative of the general population of response workers, this target group of safety professionals was familiar with the day-to-day operations of the Deepwater Horizon responders, and worked closely with them on health and safety-related issues.

The following themes, listed in order of most frequently reported, emerged from the discussions as work organization factors and job stressors for the safety professionals and individuals they supervise or oversee: (1) heat and environmental conditions, intensified by the use of PPE; (2) basic living issues (including physical and mental fatigue) and food arrangements; (3) job insecurity; (4) management and communication issues including a lack of clarity about the chain of command for decision-making and who had tasking authority and priority; (5) frequent changes in rules, procedures, and protocol; and (6) varying levels of safety knowledge, experience, and training. Indicators of job stress included loss of temper, acting out in frustration or anger, loss of enthusiasm, and low morale.

Discussion and Conclusions

These evaluations revealed the potential for numerous occupational hazards. PBZ and area air sampling at specific sites and during specific activities consistently revealed nondetectable to low levels of individual chemicals. Nonetheless, mixed low-level exposures to crude oil, dispersant, and other chemicals; heat stress, psychosocial strains, ergonomic and other injury hazards; and pre-existing personal health risk factors all may have contributed to health symptoms reported by response workers. An additional potential contributing factor for the acute respiratory symptoms reported by some response workers is the formation of reactive aldehydes and ozone from the environmental photochemical activity on volatile hydrocarbons [Goldstein et al. 2011]. Nonspecific symptoms such as headache, eye and respiratory irritation, and fatigue were more commonly reported by responders who self-reported exposures to oil, dispersants, or other chemicals compared to workers who self-reported no such exposures. While no one hazard or exposure can explain the increased reporting of such symptoms among this group of workers, eliminating or reducing all such hazards in as comprehensive a manner as possible will decrease the likelihood of health effects during future responses such as this.

Heat Stress

In most work sites evaluated, the conditions for heat stress were present, significant, and often the most pressing concern for the health and safety of response workers. Where we measured environmental conditions, temperatures often exceeded 90°F–100°F, with high relative humidity, creating conditions for severe heat strain. With the addition of required PPE such as full body coveralls and protective gloves and boots, the possibility of health effects related to heat was intensified. In response to these conditions, heat stress management plans were developed by BP and observed in use at the sites evaluated. These protocols often centered on a work/rest regimen that provided a sufficient rest period for the worker to cool and rehydrate after a work period. A common cycle was a 20-minute work period followed by a 40-minute rest and rehydration period, but this varied by site and conditions. At many locations, these cycles were strictly enforced, as was mandatory rehydration with water or electrolyte-providing beverages, which were uniformly observed to be plentiful and readily available. However, surveillance conducted by the Louisiana Department of Health and Hospitals revealed 10 workers hospitalized between May 28, 2010, and June 22, 2010. Of these 10 workers, five identified heat as a major problem and reported a variety of work-related and personal risk factors for heat illness. These five had evidence of dehydration or a diagnosis of heat exhaustion or possible heat stroke. To prevent such health effects, it is imperative to strictly adhere to heat stress management protocols at all locations. These protocols should include the provision of shaded or cooled rest areas and the improvement of worker training regarding the hazards of heat stress and the identification of early signs and symptoms of heat strain.

The role of PPE worn by workers is intended to be a protective one to prevent harmful exposures. It is imperative to conduct continual evaluations of the need for specific PPE such as full-body coveralls throughout emergency responses such as this to determine their necessity. When exposures have been evaluated and determined to be minimal or insignificant, overuse of PPE can have an unintended effect of burdening the worker with unnecessary gear that can exacerbate heat stress, limit visibility, and increase the possibility of slips and trips. It is important that trained occupational safety and health professionals develop and implement guidelines for determining when PPE use is truly necessary. Balancing the need to protect workers from potential exposures without creating unnecessary hazards for workers from too high a level of PPE is critical. Medical support staff was available at many sites where workers were required to wear PPE. This staff played an important role in monitoring possible health effects and providing on-site medical assessments with referral for higher levels of care as needed.

Chemical Exposures

A large number of chemicals was sampled for over the course of the HHE. These included VOCs, PAHs, and H_2S from the oil itself or cleaning chemicals used; VOCs, PAHs, aldehydes, CO, and particulates from combustion sources, including burning oil and natural gas or the use of gasoline-powered engines; VOCs, glycol ethers, and propylene glycol from dispersants; and diesel exhaust from the use of diesel engines. Sampling was conducted at offshore and onshore worksites during activities of concern. Our sampling strategies included full-shift air sampling using validated NIOSH sampling and analytical methods. Throughout the evaluation, results for all airborne chemicals sampled were uniformly nondetectable or at levels well below applicable OELs. The exception to this was peak CO levels likely due to the build-up of gasoline exhaust from idling outboard motors involved in in-situ burns. The results for all compounds measured at levels below detectable concentrations or at concentrations below OELs may reflect several important considerations. For example, the lack of significant exposures to VOCs may reflect the lack of high volatility compounds from the oil at those worksites. Higher volatility compounds initially present in the oil may have dissipated shortly after release and during the weathering process so that concentrations on vessels and onshore were minimal. Combustion byproducts produced at the in-situ burns did not appear to exist in high concentrations at the distance the boats maintained from the smoke plume, reflecting the upward migration of such compounds in the ascending column of smoke plume extending above the workers' location. Open air and wind action helped dilute airborne concentrations during the aerial and vessel-based dispersant releases evaluated so that concentrations at the vessel level were low.

We attempted to evaluate activities and job duties that were representative of the work responders conducted daily. The intent of the air sampling was to provide an accurate assessment of the types and levels of exposures to airborne chemicals to which the workers were exposed. On the basis of sampling results, recommendations for additional respiratory protection were not deemed necessary. However, it is recognized that changing conditions at worksites may present opportunities for exposures at levels differing from results obtained on the days NIOSH teams were present. Therefore, it is imperative that company and contractor health and safety representatives conduct thorough, full-shift and short-term exposure sampling throughout responses such as this to ensure that changing conditions can be immediately responded to and protections implemented, as warranted.

In addition to quantitative exposure sampling, we assessed work practices in a qualitative manner to identify potential hazardous exposures. In particular, we sought to identify potential dermal exposures to oil, dispersant, or other chemicals. Observational exposure characterization was performed at numerous beaches in Louisiana, Mississippi, Alabama, and Florida where cleanup was occurring. Even at beach cleaning worksites where oil residue was judged by our teams to be heavy, worker exposure to oil residue was typically observed to be limited, with no evidence of exposure to dispersant. While the use of PPE (gloves, coveralls, face shields, goggles, etc.) was typically found to be matched to the level of expected or potential dermal exposure at many sites, PPE was not always used as directed. For example, safety protocol during in-situ burns dictated the use of flame-resistant coveralls and leather gloves by the individual placing the ignition package. On several occasions, we observed that only the top half of the coveralls was donned (i.e., the worker did not step into legs of the coveralls) and no gloves were worn. Proper training and consistent PPE use is an important component in preventing dermal exposures and injuries.

Work Organization Factors and Psychosocial Stress

In addition to physical and chemical stressors, the mental and psychosocial stressors of performing response work for this type of event are an important aspect of worker safety and health. Our health symptom surveys asked about the extent of stress-related and mental health symptoms experienced during response work. Among those surveyed, the percentage of response workers who reported one or more symptoms related to psychosocial stress (feelings of “work pressure,” being worried or stressed, depressed or hopeless, short-tempered, or experiencing frequent changes in mood) ranged from 1% to 24% of those surveyed across groups. Although it is difficult from this type of survey to assess the extent to which reported symptoms were specifically related to work, the information provided by the focus groups, discussed below, was helpful in identifying work-related factors that should be addressed.

Focus group discussions on psychosocial issues revealed several themes that increased the chances of developing symptoms of stress, including heat and environmental conditions, basic living conditions, job insecurity, and management and communications issues. For example, workers in the focus groups reported being subjected to crowded and sometimes unsanitary living quarters with limited personal space or privacy. This resulted in some reports of tension and confrontations among workers. Focus group participants also reported that the long work days (generally more than 12 hours) resulted in considerable mental and physical fatigue, with little opportunity to recuperate after working many consecutive days. Uncertainty over how long the workers could expect to be employed resulted in many of the response workers feeling on edge. Confusion and frustration due to multiple, conflicting directives from various areas of the chain of command and issues related to poor communication concerning decision-making resulted in increased stress. The difficulty of being away from home and family also was regularly reported as a source of psychosocial stress.

Work organization, basic living conditions, job insecurity, and communication should be addressed in a comprehensive occupational safety and health prevention program. Development, implementation, and enforcement of clear policies and guidelines throughout a response can minimize psychosocial impacts for workers.

Ergonomics

Ergonomic issues were identified at several locations, and musculoskeletal symptoms were reported by workers in our health symptom surveys. We observed repetitive forceful movements and awkward postures of the back and upper extremities when performing lifting, pushing, and pulling activities at decontamination and waste management sites, beach cleaning, wildlife cleaning, and oil skimming and vacuuming operations. Awkward and repetitive tasks can lead to increased risk of musculoskeletal disorders, particularly in the hand, shoulder, and back. In fact, musculoskeletal injuries were the second largest category of complaints found in infirmary logs we reviewed. Health and safety professionals should evaluate tasks and work practices for ergonomic hazards and devise preventive solutions to reduce the risk of musculoskeletal injury. Qualified ergonomists may contribute to the redesign of work processes and practices as well as the development of more ergonomically efficient tools appropriate for specific tasks (e.g., for beach cleaning activities).

Tobacco Use

We observed the extensive use of tobacco, especially cigarettes and smokeless tobacco products such as chew, dip, or snuff, by response workers at the sites. The health hazards associated with the use of tobacco products are well documented; effects include cardiovascular and coronary heart disease and a wide variety of cancers, including oral cavity, laryngeal, pharyngeal, esophageal, lung, and stomach cancers. While these health effects are widely acknowledged, less is known about the role exposure to tobacco products and cigarette smoke may play in an additive or synergistic manner with exposure to other chemical or physical hazards that may be present in emergency responses. Workers should pursue strategies to quit the use of tobacco products to prevent exposures to themselves and work colleagues. Smoking should be discouraged at all worksites, including contracted vessels. Employers are encouraged to provide smoking cessation programs for employees, ideally with the goal of attaining a smoke-free workplace.

Limitations of the Evaluations

We used a combination of quantitative and qualitative exposure methods during our evaluations. The quantitative evaluations focused on air sampling for a variety of chemicals to determine levels of exposure. Observational assessments provided a qualitative measure of potential exposures to complement sampling. The combination of these approaches provided valuable information on the types and extent of worker exposures. Despite attempts to identify potential hazards and issues of importance using these two approaches, several limitations were inherent in the investigations. These limitations include the fact that Deepwater Horizon response work was stretched over an extremely large geographical area, making the evaluation of all worksites infeasible. Response work activities and exposures were quite dynamic throughout the response, so conditions at one point in time may not fully represent all conditions encountered by workers. Despite these limitations, we believe the issues we identified are applicable to the overall response. The consistency of NIOSH results and conclusions across the sites and activities we evaluated, along with consistency of our results with the quantitative measurements reported by other investigating organizations such as OSHA, USCG, and BP and its contractors, support the idea that our results have accurately characterized occupational exposures for the types of work included in our evaluations.

Occupational Health Considerations for Future Large-Scale Response Events

Our evaluations identified hazards and occupational health considerations for future large-scale emergency response events. The development and effective implementation of comprehensive occupational safety and health programs are essential to preventing adverse health effects during emergency responses. Although each event presents unique issues, our experiences reveal needs and suggest strategies that would apply to most situations.

Illness/Injury Surveillance

Because of the large scale increase in the number of workers responding to the oil release, the necessity of rapidly establishing a widespread system of surveillance for illnesses and injuries was a high priority. The Louisiana Department of Health and Hospitals established a sentinel surveillance system to track and evaluate acute health effects reported through hospital emergency departments, clinics, physicians' offices, and the Louisiana Poison Control Center. The system captured reports of workers' symptoms and hospitalizations thought to be related to Deepwater Horizon response work.

For a surveillance system to capture the needed information, we recommend making occupational exposure history a component of a complete history and physical examination administered by the examining physician or healthcare professional. This occupational history would gather important information regarding the patient's exposures to chemicals or other potentially hazardous agents, including relationship of those exposures to the onset of symptoms, and any use of PPE or other protective measures. Additionally, we recommend collecting this information on incident reporting forms collected by on-site health and safety professionals so it can be relayed to physicians or other healthcare professionals should the worker require further medical attention.

Medical Clearance and Preplacement Evaluations

Preplacement evaluations are an important component in protecting workers with job duties that pose physical, mental, and chemical hazards, especially in large-scale emergency responses where workers may be performing unfamiliar tasks in unfamiliar environments. These evaluations are not meant to be a formal fitness for duty examination, but present a unique opportunity in several respects. They help health professionals identify individuals with health concerns that need to be addressed and those with specific susceptibilities whose activities may need to be restricted or modified. They also allow health professionals to identify medication, immunization, or training needs for workers and provide valuable information to the workers themselves on their health status and potential demands of the work they will encounter. These evaluations help document the worker's health status and may provide an opportunity for the worker to be directed to further medical evaluation as necessary. Finally, these evaluations can provide baseline information on health status that may be useful for future evaluations or comparisons. Recommendations on when and what types of medical evaluations should be done and the minimum information to gather during such an evaluation can be found on the NIOSH website at http://www.cdc.gov/niosh/topics/oilspillresponse/preplacement.html.

Risk Communication

The clear and consistent use of effective risk communication strategies is critically important in emergency response events. Our experience in the Deepwater Horizon response shows that these strategies can be improved upon by all involved parties. Many groups such as response workers; the general public; the scientific and medical community; advocacy organizations; local, state, and federal government agencies; and the media sought timely and accurate information about the event. Meeting the needs of these diverse groups is challenging. We received reports that messages and information were at times insufficient for their intended audience. For example, the need for detailed, timely, and specific information on all aspects of the occupational exposure evaluations was important to the scientific community and advocacy organizations. Members of these groups described a lack of details in official reports and communications from BP. Missing details included circumstances, conditions, and specific locations during which exposure measurements were collected; specific sampling methodology used; activities the workers were performing at the time of data collection; whether the samples were general area air samples or PBZ samples; and descriptions of the quantities or presence of oil, dispersants, or other chemicals to which the workers may have been exposed. We also received reports of the necessity for improved and more widely disseminated risk messages. These messages should be conveyed in simple and easy-to-understand terms for workers and the general public. Likewise, they should be tailored to available forms of communication and use the primary language of the intended audience.

The importance of good risk communication cannot be understated. Understanding and implementing improved risk communication strategies and messages learned from the Deepwater Horizon oil release will allow for a clearer understanding of the occupational hazards faced by response workers. Such knowledge will improve our ability to respond to those hazards, and to protect workers from safety and health hazards.

Reference

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Availability of Report

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